ENGINEERING
# COMBUSTION
DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



## November, 1944

New Chesterfield Station of Virginia Electric and Power Company

## CHESTERFIELD POWER STATION

## Compressibility Factor for Superheated Steam

## Progress in Steam Engineering

# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIXTEEN NUMBER FIVE


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## FOR NOVEMBER 1944

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# EDITORIAL

## Six-Year Report on Electric Utilities

In view of the varied opinions expressed as to the present and future state of the electric utility industry, many undoubtedly based on individual cases, it is informative to read the report just released by the Federal Power Commission covering the financial record of the electric utility industry for the six-year period 1937–1943. This covers all such utilities having electric revenues in excess of $250,000 a year, which comprises approximately 98 per cent of the privately owned electric utilities.

Over the six years kilowatt-hour sales have increased 75 per cent, generating capacity 22 per cent, the number of customers 15 per cent and gross revenues 38 per cent. Despite these figures, the plant investment has increased only 7 per cent—a fact probably attributable, in part, to greater use of reserve capacity in many cases and to more extensive interconnection. The major part of the increase in output, of course, occurred in the last three years, whereas the greatest increase in number of customers was in the first three years.

The average investment in plant per dollar of gross revenue was $4.28 in 1943, by which time the operating expenses had increased 36 per cent, although there was little change in the ratio of operating expense to revenue. As might be expected, taxes practically doubled.

It is significant that the foregoing has been achieved with no increase in electric rates and at a time when general price indexes have advanced sharply, some of which, as in the case of fuel and labor, have directly affected utility operating expense.

Although the rate of return on utility bonds decreased by more than one per cent during this period, the income from operations available for investors remained nearly constant. Thus, the report concludes that the utility industry, as a whole, is now in a strong position.

## Three Terms or Two

The accelerated program of engineering courses, involving three terms of almost continuous study in our principal engineering schools, was initiated as a war measure and it is possible that there may be some agitation to extend the plan to peacetime education, especially in view of the Veterans Act which extends government assistance to those desiring to complete their education.

However, many prominent educators in the technical fields are of the opinion that it would be a grave mistake to continue the accelerated programs after peace has been declared. They feel that the plan not only does not afford sufficient time for assimilation of fundamentals, but that, in the engineering field especially, it is most desirable that the student supplement his classroom work with practical experience through summer employment in industry. They point out that such vacation jobs provide an opportunity for the student to rub shoulders with the workers and to become conversant with the latter's viewpoints, which knowledge should be of inestimable value in later years if called upon to handle any labor relations problems.

Admittedly, vacation employment, as distinguished from regular student training courses for engineering graduates as practiced by many companies, is often a burden to industry; but there is some compensation in the fact that it affords management an opportunity to size up the students' qualifications and thereby to select and follow up those it would like to employ after graduation.

The transition from a more or less war-disrupted educational system to normal procedure will take some time and educators are now properly giving much thought to what lies ahead, particularly as engineering training seems certain to play an important rôle in the post-war period.

## Close Collaboration Needed

A given steam turbine will operate equally well in the East, the West, or abroad, so long as the steam conditions are appropriate. Steam, its motivating medium, knows no geographical limits. The same may be said of some other power apparatus, but not of fuel-burning equipment, particularly stokers. Excepting perhaps the spreader type which carries wider latitude in fuel selection, stoker designs are predicated on the characteristics of the fuel available to the localities in which they are to operate. Not only do the coals themselves vary over a wide range, but mining methods, blending practices, sizing and marketing conditions are changing. To a lesser degree this situation also applies to pulverized coal firing in which grindability and ash characteristics are most important.

It therefore behooves coal producers, marketers and stoker manufacturers to work in close collaboration, to the end that each may be fully conversant with the others' problems and the user be guided in the selection of equipment and the purchase of coal to suit it.

Recognizing that coal producers, equipment designers and users had a mutual problem, the Coal Division of the A.I.M.E. and the Fuels Division of the A.S.M.E. several years ago initiated joint annual conferences. This year, because of railroad traffic congestion, the meeting which was held at Charleston, W. Va., late in October was made a local meeting, rather than one national in scope. Although the reason was sound, it was most unfortunate that this should have been necessary at a time when the fuel situation is more chaotic than it has been in many years.

# CHESTERFIELD POWER STATION, Virginia Electric and Power Co.

By F. H. SPIES, Plant Superintendent

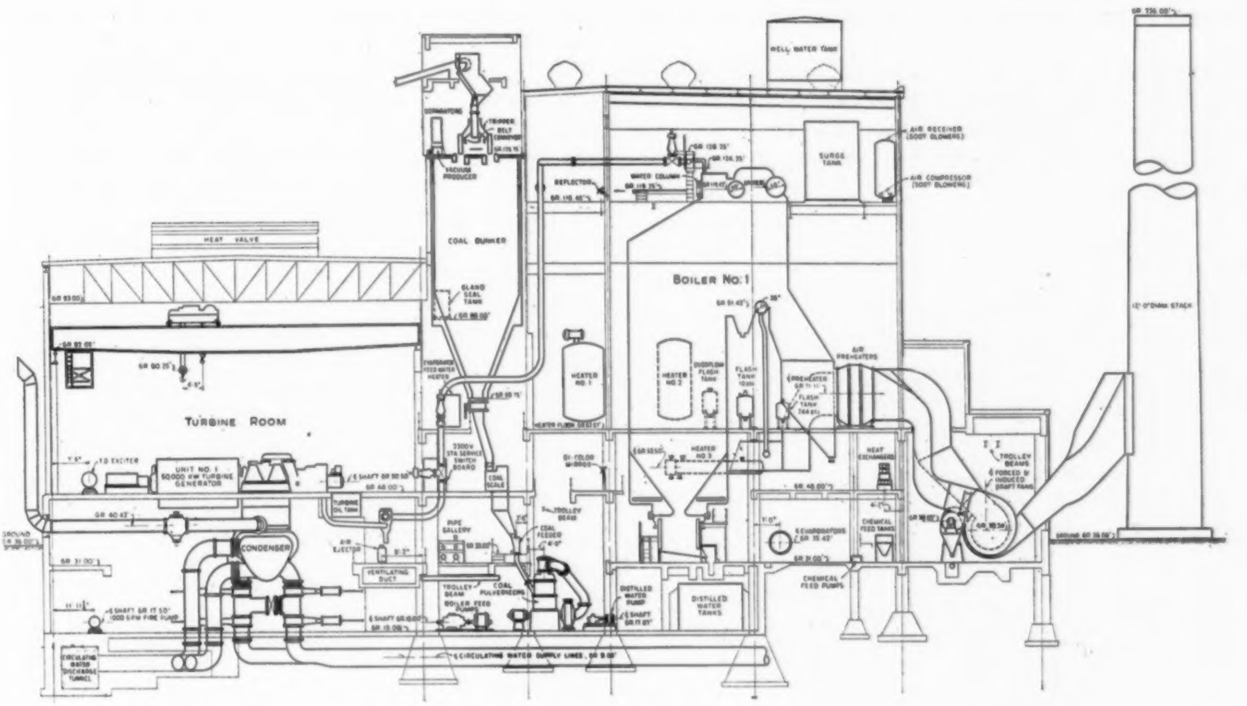
**Because of the materials situation existing at the time this new station was designed, unusual expedients were adopted in the building construction in order to use a minimum of steel; also transite conduit and substitutes for rubber insulation were employed throughout. Built on the unit plan with an initial capacity of 50,000 kw and a contemplated ultimate capacity of 200,000 kw, the station employs 875 psi pressure and 900 F total steam temperature.**

A 50,000-kw capacity unit was placed in operation at the Chesterfield Power Station on July 31, 1944. It represents the sixth major addition to the generating facilities of the Virginia Electric and Power Company since 1936, and the first unit in a new power station having an ultimate capacity of perhaps 200,000 kw. This station is located on a 200-acre tract of land on the south bank of the James River, approximately 15 miles south of Richmond, Va.

The station was engineered and constructed under the supervision of the Stone & Webster Engineering Corporation. Purchase of equipment and construction materials was largely made in 1942 at a time when the procurement of such was most difficult due to the wartime restrictive programs of various government agencies. Therefore, simplifications and minimum use of critical materials became the keynote of design.

A single-unit station comprising a condensing turbine-generator, a pulverized-fuel-fired steam generator, and a step-up transformer bank was given favorable consideration. Equipment was urgently needed because of rapidly increasing war loads and the capacities selected were primarily determined by the expediency with which the equipment could be secured. It is believed, however, that the unit station selected formulates a satisfactory basic design for future extensions to Chesterfield Power Station.

**Erection view showing transite siding applied to wood girt system**




**Section through station**

*Building Construction*

The main power station building is approximately 240 ft. long, with varying widths from 90 ft at the boiler room to 113 ft at the turbine room, and with varying heights above ground elevation from 67 ft at the turbine room to 106 ft at the boiler room. The entire structural frame from the condenser floor to the turbine operating floor and to the burner floor in the boiler room is constructed of reinforced concrete. This type of construction is applied to the entire coal bunker area including the 1500-ton capacity coal bunkers. Reinforced concrete columns of 2 ft 6 in. by 5 ft 6 in. cross-section support the coal bunkers and one runway of a 100-ton capacity turbine room crane. Structural steel framing is confined to the outside walls, to the roof, and to the boiler supports. The exterior walls are constructed of corrugated asbestos cement siding supported on wood girts attached to the steel structural framing. Wood sash and doors are used throughout the station except where fire doors are required. The roof design utilizes precast cement tile supported on wood purlins in the turbine room and steel purlins in the boiler room. Stairs and walkways are constructed of steel framework with precast cement stair-treads and tile. Wood hand railings are used throughout. Duct-work for the distribution of filtered air for station ventilation is also constructed of reinforced concrete.

All auxiliary structures and buildings which are of a permanent nature are of the same general construction. The departure from normal power plant practice in the design of the buildings required the use of some 25,000 cu yd of concrete; whereas, normal practice would have required only approximately 10,000 cu yd.

*Steam-Generating Unit*

Steam for the station is supplied by Combustion Engineering Company steam-generating equipment. This unit is pulverized-coal fired and rated at 525,000 lb per hr steam delivery for continuous operation, or 575,000 lb per hr for four-hour peak operation. Steam conditions at the outlet of a two-stage interbank superheater are 875 psi gage pressure and 900 F total steam temperature.

The boiler is a three-drum bent-tube type with a completely water-cooled furnace of the sloping-tube dry-bottom type. It is enclosed by a removable sectional transite casing except over the roof and headers which are encased with steel plate. The furnace is designed for a heat release of 19,600 Btu per cu ft per hr at rated capacity. Average furnace heat absorption at rated capacity is 56,600 Btu per sq ft per hr with a maximum heat absorption of 62,200 Btu per sq ft per hr. The boiler has a heating surface of 23,645 sq ft, the water walls 10,560 sq ft and a furnace volume of 34,500 cu ft.

The furnace is arranged for tangential firing. Fuel burner equipment consists of twelve coal burners, four fuel oil burners for light steaming purposes and four fuel-oil ignition torches. Three coal burners, one oil burner and one ignition torch are located in each corner of the furnace. The coal burners are arranged for adjustment in the vertical plane by remote manual control from the boiler operating board. This adjustment in conjunction with the operation of the superheater by-pass damper is used to control superheat temperature and to improve firing conditions in the furnace at light loads.

Three 14-ton per hour bowl-type pulverizers with integral exhausters and separate floor-type feeders are pro-

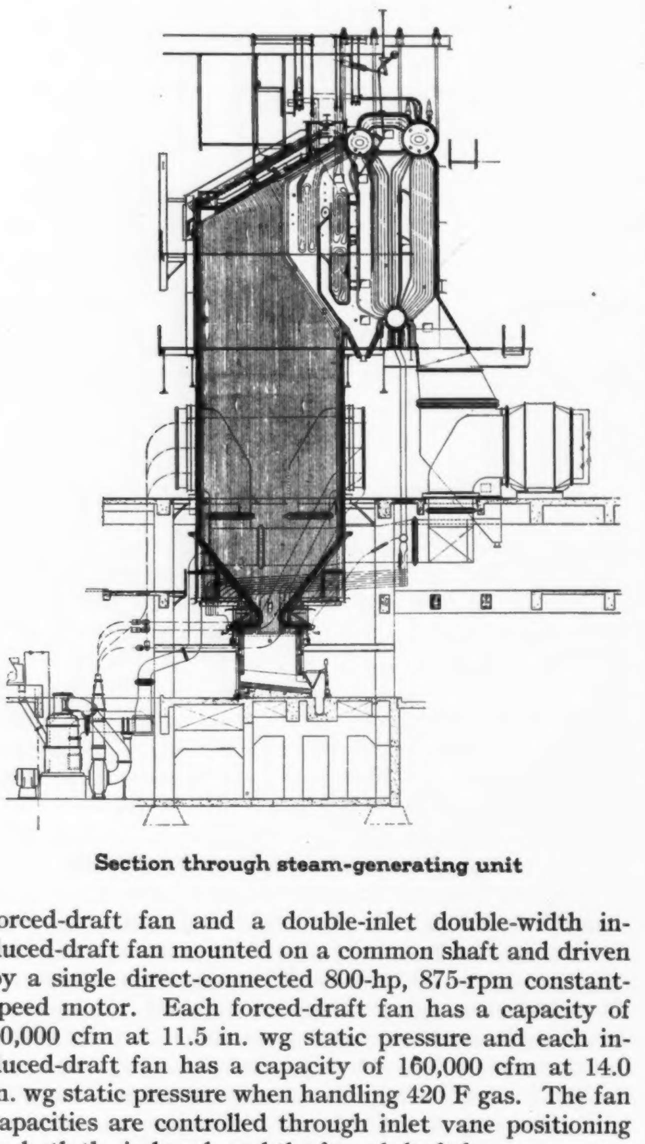
vided. Each mill supplies one burner per corner. The capacity of the pulverizers is such that the boiler can be operated at rated steam output with one mill out of service.

Two horizontal-shaft Ljungstrom regenerative-type air preheaters are installed at the boiler gas outlet. Each of these has 31,300 sq ft of heating surface.

The calculated performance of the steam-generating unit is as follows:

| | | | |
|---|---|---|---|
| Actual evaporation, lb per hr | 265,000 | 400,000 | 525,000 |
| Feedwater temperature, F | 331 | 355 | 380 |
| Total steam temperature, F | 854 | 900 | 900 |
| Boiler exit gas temperature, F | 630 | 700 | 760 |
| Air heater exit temperature, F | 355 | 378 | 405 |
| Overall efficiency, per cent | 86.5 | 86.2 | 85.6 |

Two Sturtevant duplex draft fan units serve the steam generator. Each duplex unit consists of a single-inlet forced-draft fan and a double-inlet double-width induced-draft fan mounted on a common shaft and driven by a single direct-connected 800-hp, 875-rpm constant-speed motor. Each forced-draft fan has a capacity of 90,000 cfm at 11.5 in. wg static pressure and each induced-draft fan has a capacity of 160,000 cfm at 14.0 in. wg static pressure when handling 420 F gas. The fan capacities are controlled through inlet vane positioning on both the induced- and the forced-draft fans.



**Section through steam-generating unit**

The duplex fan units have integral auxiliary equipment for cinder elimination at the induced-draft fan inlets. This consists of an auxiliary motor-driven fan at each induced-draft fan inlet and cinder collector. A centrifugal force is imparted to the exit gas as it passes through the inlet boxes, which causes the cinders to be thrown to the periphery of the volute boxes. The auxiliary fans function to "skim off" the cinder-laden gas following the periphery, to pass it through the cinder-separating cyclones and finally to discharge the cinder-free gas back to the fan inlet box. The cinders are deposited in a water-sealed hopper and are removed continuously.

It is estimated that the cinder-eliminating equipment will operate at approximately 85 per cent efficiency and that this will be sufficient to prevent excessive erosion of the inlet vanes, rotating element, and housing. It will also be sufficient to prevent a dust nuisance in the rural district near the plant.

Boiler gases are discharged to a perforated radial-brick stack of 12 ft inside diameter, and 200 ft in height above the foundation mat at ground elevation. The stack is provided with flood lighting in compliance with the aviation obstruction marking requirements.

The ash-handling equipment for the dry-bottom furnace consists of a sectional cast-iron refractory lined ash hopper, oscillating ash rejection nozzle assemblies, sluiceways, one stationary double-roll clinker grinder, two ash pumps and the necessary piping to convey the pump discharge to a waste land dump.

### *Turbine-Generator*

The Chesterfield Station turbine-generating unit is of General Electric Company manufacture. The generator is hydrogen cooled and is rated at 50,000 kw, 0.8 power factor, three-phase, 60-cycle, 3600 rpm, 13,800 volts and is designed for a 0.9 short circuit ratio. When operating on air the generator can be operated at 60 per cent of its kva rating. With the hydrogen pressure increased from a normal $^1/_2$ psig to 15 psig, the generator capacity is increased to 72,000 kva at 0.88 power factor. The main and pilot exciters are air cooled and are driven from the main shaft through a 2-to-1 reduction gear.

The turbine has 21 stages and is designed for throttle conditions of 850 psig pressure and 900 F total steam temperature, and with exhaust to a surface condenser. Four stages of extraction are provided for regenerative feedwater heating and supply to a 200-psig auxiliary header. Overload capacity is 62,500 kw. Following is the calculated performance of the turbine-generator based on nonextraction operation:

| Load on Unit, Kw | Power Factor | Water Rate at 1.75" Absolute Pressure | Water Rate at 1.5" Absolute Pressure |
|---|---|---|---|
| 62,500 | 1.00 | 7.84 | 7.80 |
| 56,250 | 0.90 | 7.78 | 7.74 |
| 50,000 | 0.80 | 7.74 | 7.69 |
| 37,500 | 0.80 | 7.84 | 7.74 |
| 25,000 | 0.80 | 8.16 | 8.05 |

The surface condenser is a two-section single-pass unit having 35,400 sq ft of condensing surface, with steel tube sheets and Admiralty metal tubes. Circulating water is supplied by two 45,000-gpm vertical propeller type submerged circulating water pumps located in a screen well at a pump house on the river bank. The intake well structure at the pump house is equipped with two traveling screens, each 8 ft wide and 42 ft long.

### *Electrical Equipment*

The turbine-generator leads are carried overhead directly from the generator through the turbine room wall to a wood-pole bus structure on the south side of the building. Two 3000-amp 1,000,000-kva interrupting capacity oil circuit-breakers are connected in tandem in the generator to the step-up transformer circuit.

The step-up transformer bank consists of three 20,000-kva 13,200/66,450-volt (115,000 volt Y) single-phase

General view of steam-generating unit

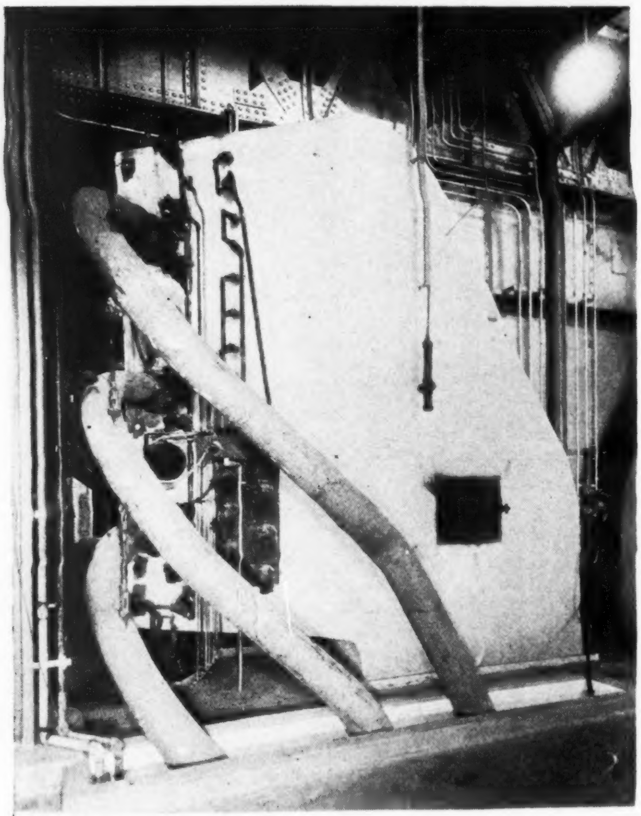
oil-insulated forced oil- and air-cooled transformers. Each transformer has two integral copper fin-type steel-tube radiators supported from an extension of the transformer base at each end. Valves are provided in the oil ducts between the tank and radiators so that the radiators can be removed without draining the tank. The radiators are served by individual motor-driven centrifugal oil pumps. These pumps and motors are completely immersed in oil, the oil being circulated through the motors by means of a hollow shaft. Heat dissipation is promoted by nine forced-air fans on each radiator. These fans operate in groups of three and are under automatic thermostatic control. With one radiator, including fans and oil pump, out of service the transformers have a capacity of 14,000 kva each.

A 13-mile single-circuit wood-pole H-frame, 110-kv transmission line with two ground wires connects the circuit. This provides a flexible switching arrangement with minimum equipment. Station service power can be supplied by the generator if the transmission-side breaker is open or by the transmission line if the generator-side breaker is open.

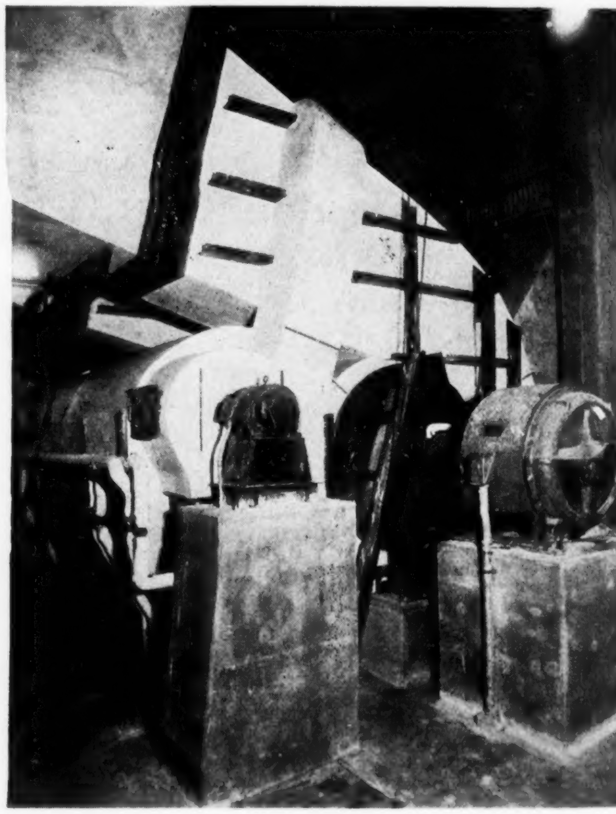
*Boiler Feedwater Heating*

The water cycle for the station employs three feedwater heaters and utilizes steam from four stages of extraction. The first and second heaters are of the vertical cylindrical shell direct-contact type, whereas the third heater is of the horizontal bent-tube closed type.

The No. 1 heater utilizes steam from the 18th stage extraction; the No. 2 heater from the 12th stage extraction; and the No. 3 heater from the 6th stage extraction. The 3rd stage extraction supplies steam for the operation of feedwater evaporators and for the 200-psig steam



**Burner arrangement at one corner**



**I.D. fan with cinder eliminating equipment**

Chesterfield Power Station to the Virginia Electric and Power Company transmission system near Petersburg, Virginia.

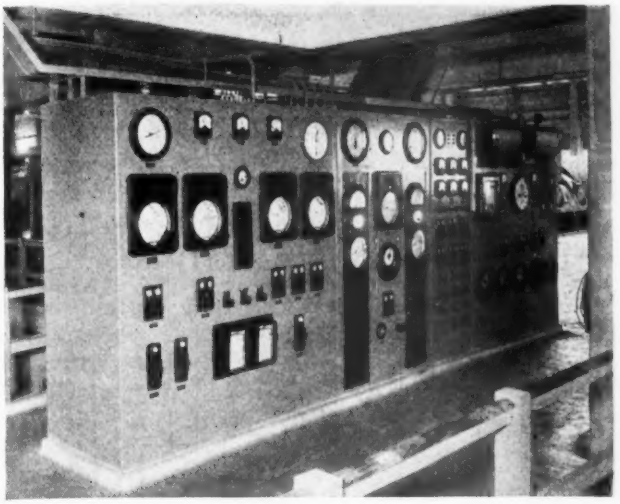
Two voltages are employed for station service, all power load in excess of 100 hp being fed directly by individual 2300-volt feeders, and 460-volt power is provided for general station use. The 2300-volt service power is obtained from a 5000-kva bank of 13.2/2.3-kv transformers installed at the outdoor structure. The 460-volt power is obtained from two 2.3 kv/460-volt three-phase transformers located in the main power station building. All station service power is distributed from metal-clad withdrawal-type air circuit-breaker switchgear.

The 2300-volt station service transformer bank is connected solidly between the two 13,800-volt oil circuit-breakers in the generator to the step-up transformer bank

header. A 900- to 200-psig reducing and desuperheating station supplements the 3rd stage extraction in supplying the low-pressure header demand.

Condensate from the condenser hotwell is pumped by two 438,000-lb per hr centrifugal motor-driven pumps to the No. 1 heater. The latter discharges to the suction of two 500,000-lb per hr motor-driven centrifugal booster pumps which, in turn, deliver water to the No. 2 heater. The No. 2 heater discharges to the suction of three boiler feed pumps which deliver the water by way of the closed type No. 3 heater to the boiler. The boiler feed pump equipment consists of one 305,000-lb per hr motor-driven pump, one steam-turbine-driven pump of the same capacity, and one 550,000-lb per hr steam-turbine-driven centrifugal pump.

All boiler feedwater makeup and cooling water for the



Boiler control board

station originates from the James River. Precipitator equipment of 1300 gpm capacity was installed to supply clarified water to bearing cooling coils, raw-water seals, turbine-oil and hydrogen-cooling equipment, and to the equipment supplying station makeup. The use of clarified water on heat-exchange equipment will facilitate maintenance of high-efficiency heat transfer.

Boiler feedwater makeup is supplied by single-effect 24,000-lb per hr bent-tube evaporators, the water in the evaporators having been filtered and softened. Internal treatment of boiler water to date has consisted of maintaining a desired alkalinity and phosphate concentration, and the adjustment of a continuous blowdown to limit silica and total solid concentration.

*Coal Handling*

Coal is handled in the yard by diesel-operated tractor equipment and an eleven-yard capacity scraper. The storage capacity of the coal yard is approximately 150,000 tons. A 30-in. rubber belt conveyor having a capacity of 200 tons per hour is employed for moving coal from the yard to the overhead bunker in the station. This belt conveyor is housed by transite sheeting and equipped with a magnetic pulley, a hammer-type coal crusher and metering equipment.

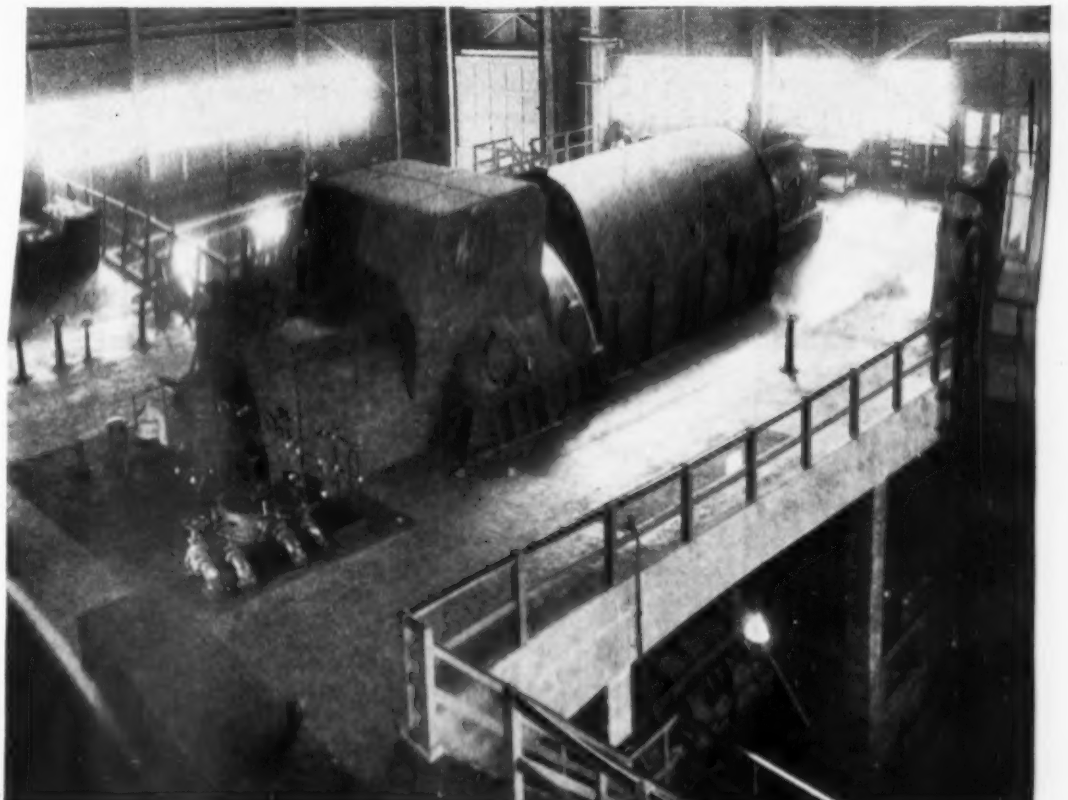
The extensive use of combustible materials for structural purposes at Chesterfield dictated that fire-fighting equipment of elaborate installation was necessary. A motor-operated 1000-gpm fire pump which takes its suction from a trapped section in the circulating water discharge tunnel was installed in the station. A duplicate capacity pump with a gasoline-engine drive was installed outside of the main power station building, and takes its suction directly from the river. A complete network of fire lines with suitably located hydrants and hose equipment is provided. Also, the oil room and part of the conveyor system are provided with automatic sprinkler protection.

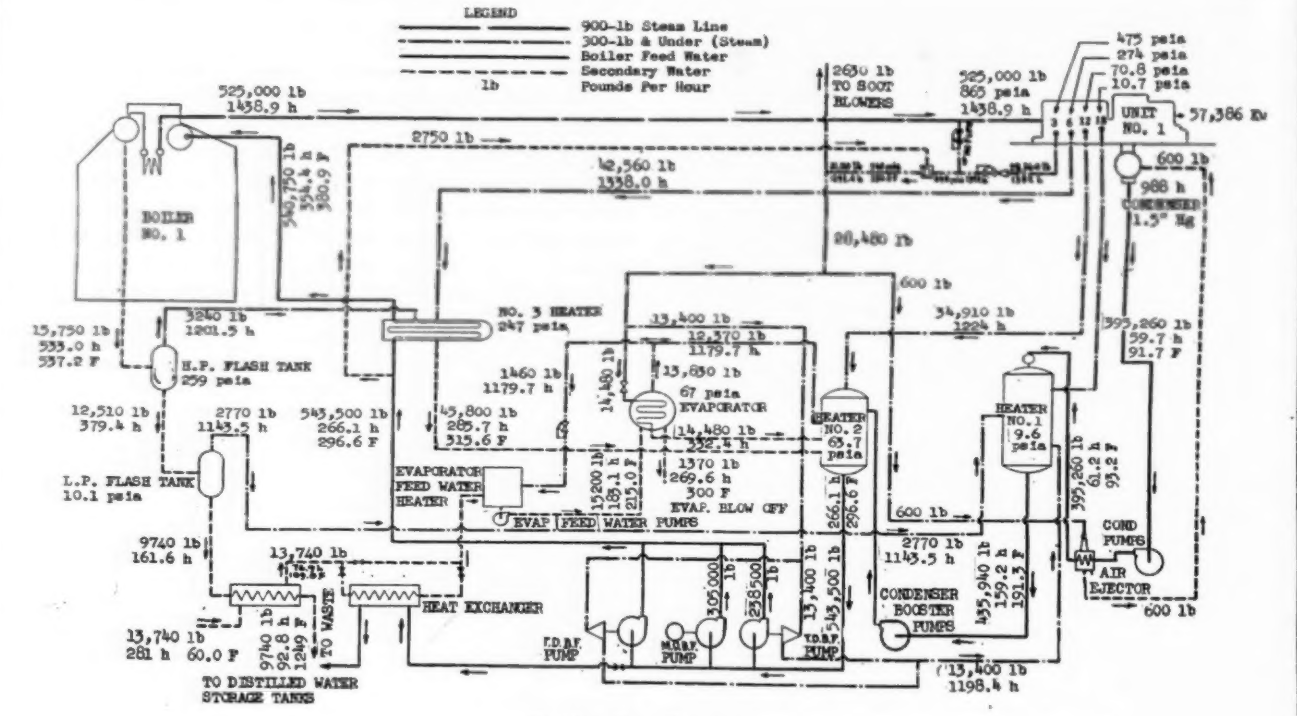
Conservation of critical materials was made wherever possible in the construction of Chesterfield Station. The substitution of concrete for steel in the construction of the building superstructure, coal bunkers, air ducts, etc., was done at a large expenditure of man-hours and money. The extensive use of wood has injected an element of high maintenance cost or eventual replacement.

Many other interesting substitutions were made. Electrical metallic tubing and transite conduit were used almost exclusively in the place of iron products. Conduit junction boxes and pull boxes were fabricated from sheet transite. No rubber-insulated wire was used on the job, all wire being of synthetic, varnished cambric, or oil-base compound insulation.

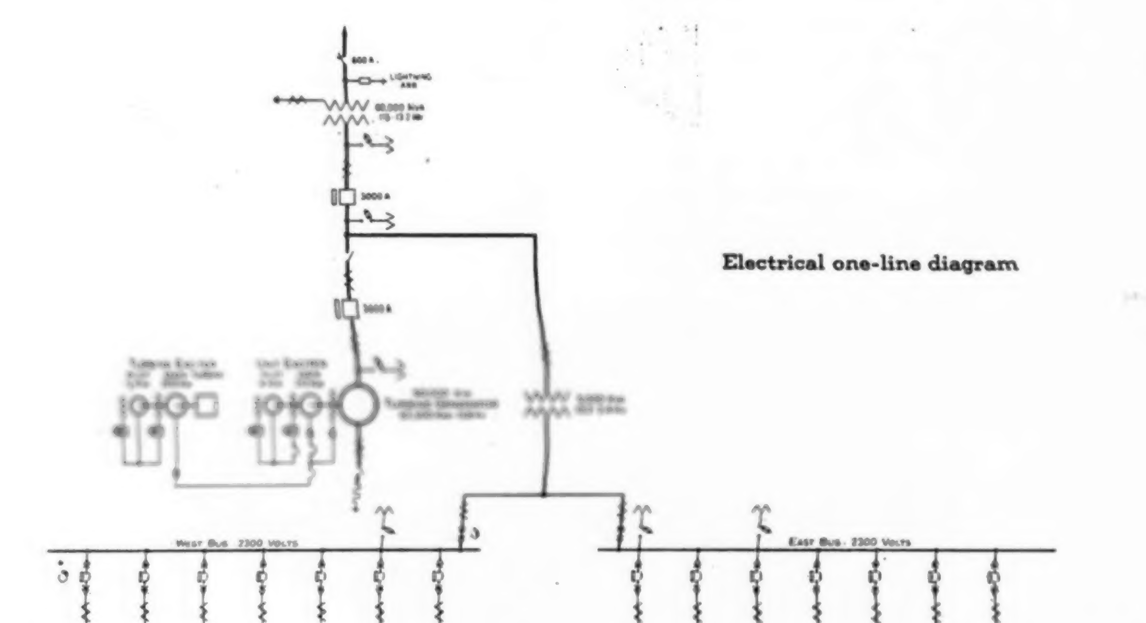
The 48-in. underground pipes which supply circulating water from the screen-well pumps to the condenser are constructed of sectional reinforced concrete prefabricated pipe. These pipes, approximately 350 ft in length, would normally be fabricated of steel plate with a protective coating.

View of turbine room and condenser well






**Station flow diagram**




**Electrical one-line diagram**

The forced oil- and air-cooled 60,000-kva transformer bank, though less efficient than a self-cooled transformer bank, was selected because of a 40-ton saving in critical materials, which represented a 35 per cent saving.

Brief mention was previously made of the use of transite sheeting for the boiler casing, transite siding for the coal conveyor, steel tube sheets in the condenser, and carbon steel tubes in the high-pressure heater where engineering judgment dictated the use of cupro-nickel tubes.

At this writing the Chesterfield Power Station has been in operation approximately ten weeks. Preliminary tests have indicated that a large percentage of the equipment is operating satisfactorily and meeting the manufacturers' efficiency guarantees. The steam-generating equipment and the turbine-generator have been subjected to full load tests. Steam loads of 640,000 lb per hr and electrical loads up to 69,000 kw at unit power factor have been carried. Auxiliary equipment under these tests functioned satisfactorily.

The continuous operating capacity of Chesterfield Station is not less than 60,000 kw with reliable peak capacity of 65,000 kw. On the basis of 60,000 kw capacity this new station was constructed at a cost of approximately $103 per kw of capacity. This compares very favorably with the cost of installed capacity prior to the war.

Operating records indicate that at loads averaging 50,000 kw the station heat consumption is 11,700 Btu per net kilowatt-hour and that the station is operating at an overall efficiency of 29 per cent.

## Principal Equipment, Chesterfield Power Station

**Virginia Electric and Power Company**

(Space does not permit a complete listing)

**Location**—Chester, Va.
**Initial capacity**—50,000 kw
**Operating conditions,**
Pressure—875 psig at superheater outlet
Total Steam Temperatures—900 F

Designed and built by *Stone & Webster Engineering Corp.*, 1942–44

**Steam Generating Equipment**—Furnished by *Combustion Engineering Company*

Boiler—One 3-drum, 3-pass, bent-tube, dry-bottom type; rated at 525,000 lb per hr, continuous or 575,000 lb per hr for 4 hr; 975 psig design pressure; equipped with *Elesco* two-stage, convection interbank superheater, with bypass damper control (*Hagan Corp.* positioner); and two *Ljungstrom* regenerative-type, horizontal-shaft air preheaters. Steam washer of the *C.E.* bubble type. Effective heating surfaces—boiler, 23,645 sq ft; water walls, 5442 sq ft; superheater, 14,100 sq ft; air preheaters, 62,600 sq ft (total). Furnace volume 34,200 cu ft

Boiler Accessories—Safety valves, one 2½-in. and five 3-in. *Consolidated* on steam drum and two 3-in. *Consolidated* on superheater. Blowoff valves, *Cochrane* tandem type; stop, check, blow-down drum-vent and drain valves, Edward; continuous blowdown, Ludlow; and blowoff tank, Richmond; water columns, *Diamond*; steam gages, Crosby; sootblowers, *Diamond*; embrittlement detector, *Hagan*.

Fuel Burners—Tangential, 3 for pulverized coal and one for oil in each corner of furnace; also 4 electrically ignited oil torches; fuel oil pump set supplied by *The Engineer Company* with *Ruggles-Klingemann* valves.

Pulverizers—Three *C.E.-Raymond* bowl mills of 28,300 lb per hr capacity with 6 per cent moisture and 550-F air; each driven by a 200-hp *Allis-Chalmers* motor

Fans—Two duplex with cinder collectors, *B. F. Sturtevant;* forced-draft fans, 68½ in. wheel diameter and induced-draft fans 84¼-in. wheel diameter; driven by 800-hp, 875-rpm *Allis-Chalmers* motors

Combustion Control—*Bailey Meter Co.*

Ductwork—*Connery Construction Co.*

**Coal Handling Equipment**

Capacity, 200 tons per hr to boiler house, 175 tons per hr to and from storage; supplied by *Link Belt Company*

**Ash-Handling Equipment**

*Allen-Sherman-Hoff* system, capacity 1000 gpm of ash-laden water

**Fly Ash Handling**

*United Conveyors* system of 9 tons per hr capacity. Ash sluice pumps *Ingersoll-Rand* driven by 125-hp *Allis-Chalmers* motors

**Steam Turbine-Generator**

One 50,000-kw (62,500 kw overload), 850 psig, 875 F normal at throttle, 3600-rpm 4 points extraction, hydrogen-cooled—*General Electric Co.*; with one direct-driven 210-kw exciter. Also one 250-kw *G.E.* exciter driven by *Terry* steam turbine

Turbine Auxiliary Equipment—Oil filtering and storage, *S. F. Bowser* system; *Turbine Equipment Co.* oil conditioning with *De Laval* "Uni-Matic" oil purifiers. Atmospheric relief and bleeder reverse-current valves furnished by *Atwood & Morrill Co.*

**Surface Condenser**

One horizontal, single-pass, 35,088-sq ft, 425,-000-lb per hr condenser with 312-sq ft twin external air precooler, and Admiralty seamless tubes expanded and belled at both ends, furnished by *Ingersoll-Rand Co.* and equipped with air ejectors

Condenser circulating-water pumps—two vertical, one-stage propeller type, each rated at 35,000 gpm with 2-ft suction and 38 ft normal dynamic head and driven by 450-hp 3-phase, 2200-volt *Westinghouse* motors

Condensate pumps—Two horizontal, three-stage impeller type, each rated at 340,000 lb per hr under 223 ft normal dynamic head and driven by two 75-hp 3-phase 440-volt *Westinghouse* motors

Circulating water lines furnished by *Warren Foundry & Pipe Co.;* circulating water valves of the flanged gate type by *Chapman Valve Mfg.* Co.; and other valves by *Homestead*, Elliott, and Swartwout

**Water-Softening Equipment**

Sodium zeolite softener system—*The Permutit Co.*

**Boiler Feed Pumps**

One 305,000-lb per hr turbine-driven; one 305,000-lb per hr motor-driven and one 550,000-lb per hr turbine-driven, furnished by *Allis-Chalmers Mfg. Co.*

**Feedwater Regulators**

Two 6 in. "Copes" type. Boiler feed-pump speed control for turbine-driven units, *Swartwout* type

**Feedwater Heating Equipment**

Low-pressure (18th stage), one vertical, direct-contact deaerating *Cochrane* type; intermediate (12th stage), one vertical direct-contact tray *Cochrane* type; high-pressure, one horizontal, closed, bent-tube, 4-pass *Griscom-Russell* type. Flash tanks, *Richmond Engineering Co.* Automatic control for the feedwater heaters supplied by *The Swartwout Co.*

**Evaporators**

Two horizontal, submerged, bent-tube *Griscom-Russell* type, 54-in. diameter and 17 ft 5⁹/₁₆ in. overall. Evaporator feedwater heater consists of one cast-iron, vertical, open, deaerating *Hoppes* type having 180 gal storage of 215 F water. Evaporator feed pump, one 2-in. 2-stage *Worthington* type

**Feedwater Treatment**

Phosphate and sulphite mix tanks furnished by *Connery Const. Co.*

Phosphate feed pumps—two triplex single-acting plunger type of *Worthington* design with *Falk* drive

Sulphite feed pumps—*Milton Roy* type, motor-driven

Phosphate feeding equipment supplied by *Hagan Corp.*

**Air Compressor Equipment**

One 500-cfm *Bury* steam-driven compressor
One 304-cfm *Ingersoll-Rand* motor-driven compressor
Compressed air back-pressure valve, *Mason-Neilan*

**Miscellaneous Pumps** for distilled water, low-head cooling, drip returns, sumps, etc., supplied by *Ingersoll-Rand, Worthington, Allis-Chalmers* and *Yoemans Bros.*

**Fire Pumps**

One 1000-gpm, single-stage *Allis-Chalmers* pump driven by gasoline engine
One 1000-gpm *Worthington* motor-driven pump

**Instruments**

Two venturi-type boiler feed flow meters supplied by *Builders-Providence, Inc.*
Drum water-level indicator of *Reliance* "Eye Hye" type
Two multipointer draft gages of *Hays* type
Boiler meter, turbine-flow meter, fluid meters and other flow meters and recorders supplied by Bailey Meter Co.
Flowmeter for boiler blowdown recirculation of Cochrane design
Temperature, conductivity and $CO_2$ recorders supplied by *Leeds & Northrup*
Conductivity recorder, *Hagan*
Recording temperature, pressure and vacuum gages furnished by the *Bristol Co.*
Other gages by *Meriam Inst. Co., Manning, Maxwell & Moore, Foxboro Co., Crosby Steam Gage & Valve Co.* and *C. J. Tagliabue*

**Pressure-Reducing and Desuperheating Equipment** supplied by *The Swartwout Co.*

**Valves**

High-pressure feedwater valves, 900-lb, both *Chapman* and *Powell*
High-pressure steam valves, 900-lb, *Chapman*
Cast-iron valves, *Crane* and *Powell*
Miscellaneous valves, *Chapman, Edward, Crane, Manning, Maxwell & Moore, Ohio Injector, Kieley & Mueller, Atwood & Morrill, Ashton, Powell* and *Klingerit*

**Piping**

High-pressure steam and feed piping furnished by *Grinnell Co.*
Fabricated piping, by *National Valve & Mfg. Co.*
Atmospheric relief, by *Richmond Engrg. Co.*
Low-pressure steam and water lines, by *E. B. Badger & Sons Co.*
Gaskets, *Flexitallic*
Traps, *Armstrong*

**Turbine Room Crane**

100-ton, supplied by *Harnischfeger Corp.*

**Electrical Equipment**

Transformers supplied by *Westinghouse* and by *General Electric*
Switchgear equipment, by *General Electric*

# Compressibility Factors for Superheated Steam

By G. A. HAWKINS† and J. T. AGNEW

PROBLEMS often arise which require the engineer to determine values for the specific volume of steam at pressures and temperatures between those found in tables, which necessitates one or more interpolations. The following method is presented for easily determining the specific volume of superheated steam where precise results are not required.

The equation of state for an ideal or perfect gas is often written in the following form:

$$pv = RT \qquad (1)$$

In this relation $p$ is the pressure, $v$ the specific volume, $R$ the gas constant and $T$ the absolute temperature.

Equation (1) may be made applicable for real gases and vapors by introducing the compressibility factor $Z$.

$$pv = ZRT \qquad (2)$$

The factor $Z$ is a function of the pressure, the temperature, and the kind of gas or vapor. Compressibility factors for many of the real gases and vapors may be found in the literature.

The authors have computed the compressibility factors for superheated steam using the data from "Thermodynamic Properties of Steam" by Keenan and Keyes.

Equation (2) when used for superheated steam may be simplified by replacing the gas constant $R$ by 1544/18 or 85.8. Equation (2) applied to superheated steam is

$$pv = Z\,85.8T \qquad (3)$$

The computed compressibility factors so obtained are plotted in the Charts I, II and III. Charts II and III have been included at the suggestion of Dr. Max Jakob of Illinois Institute of Technology. The use of the charts is illustrated by the following example:

Compute the specific volume of superheated steam at 815 psi pressure and 812 F.

The compressibility factor as found from the charts is 0.935. Solving equation (3) for $v$ gives

$$v = \frac{Z(85.8)T}{p}$$

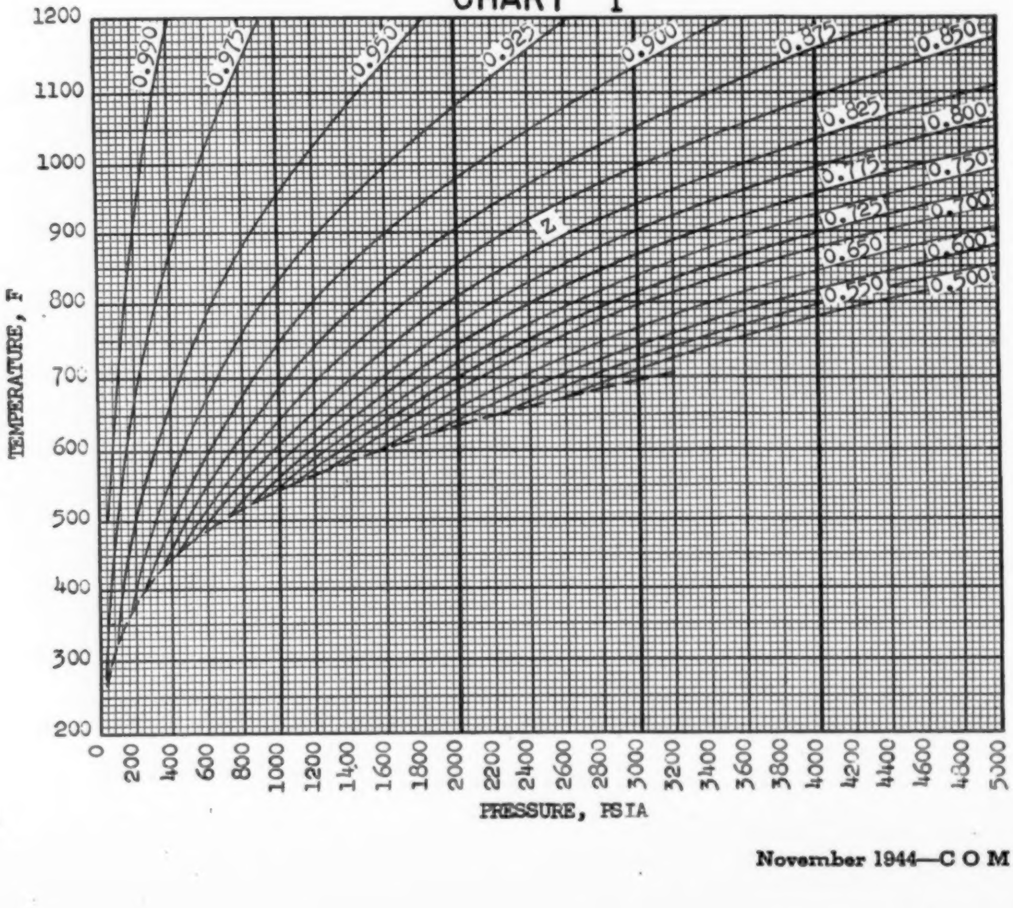
Substituting

$$v = \frac{0.935(85.8)\ (812 + 460)}{815(144)} = 0.870\ \text{ft}^3/\text{lb}$$

An examination of the chart reveals that the ideal gas equation may be used for the case of superheated steam for low pressures and high temperatures. At high pressures, the deviation from the ideal gas law is very great.

† Professor of Thermodynamics, Purdue University.

CHART I



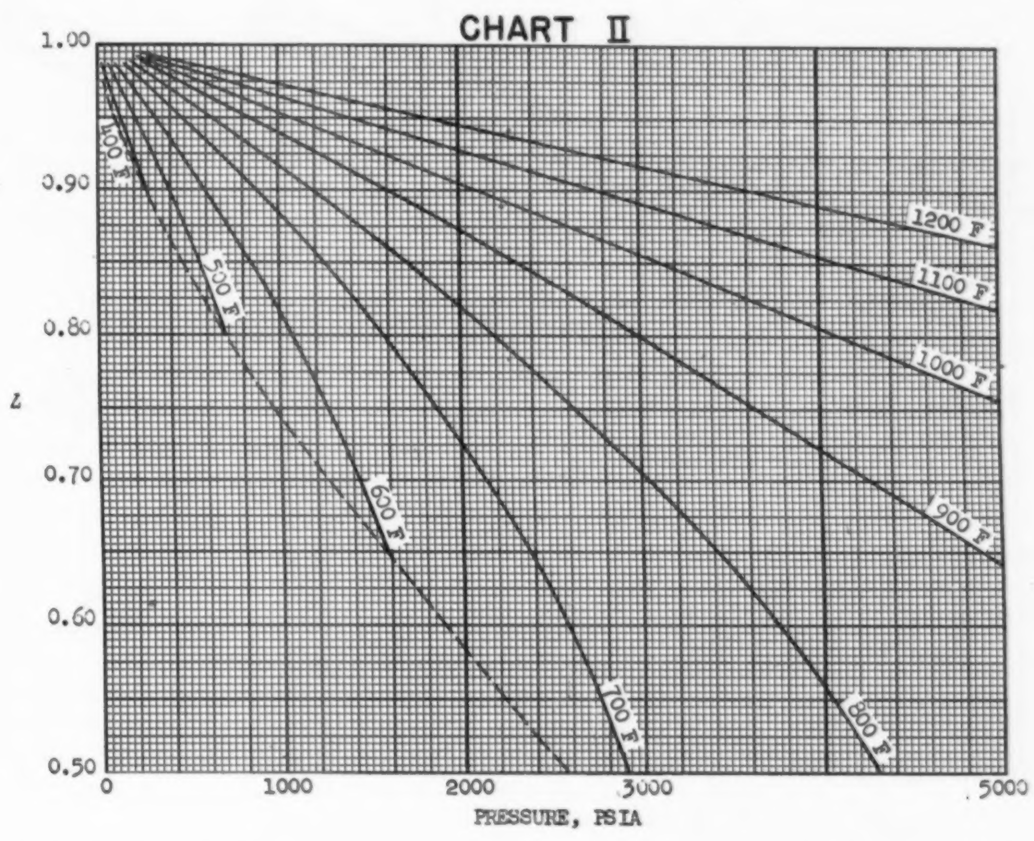


CHART II
1.00
0.90
0.80
Z
0.70
0.60
0.50
0
1000
2000
3000
5000
PRESSURE, PSIA
400 F
500 F
600 F
700 F
800 F
900 F
1000 F
1100 F
1200 F

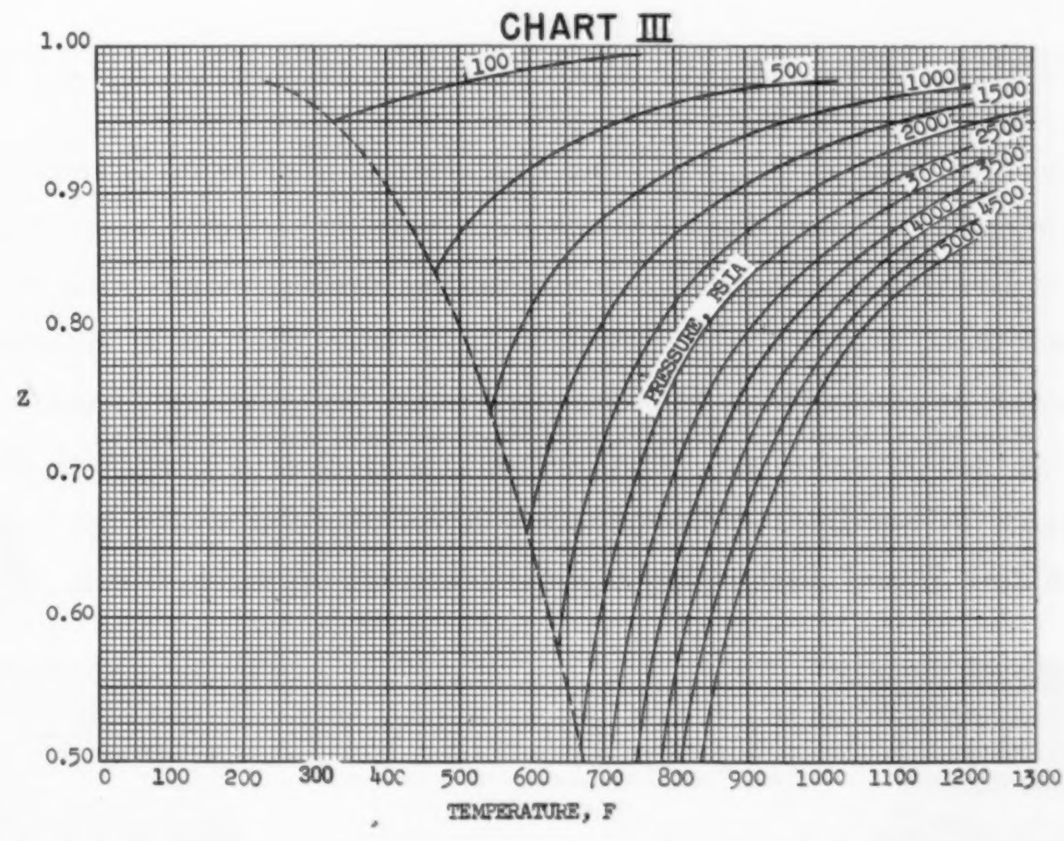


CHART III
1.00
0.90
0.80
Z
0.70
0.60
0.50
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
TEMPERATURE, F
PRESSURE, PSIA
100
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

# Progress in Steam Engineering

By C. B. CAMPBELL

Manager, Steam Engineering
Westinghouse Electric and Manufacturing Co.

**In the following excerpts from a talk before a committee of the Edison Electric Institute, the author reviews current turbine developments; discusses probable trends in steam pressures and temperatures and the effect of advances in metallurgy; and comments on the proposed A.I.E.E.-A.S.M.E. Standards as to ratings and steam conditions for units from 10,000 to 60,000 kw capacity.**

IN THEIR order of importance, recent and current turbine developments fall under one or more of the following general categories: (1) improvement of unit reliability; (2) adaptation to improved thermal cycles; (3) improvement of turbine efficiency itself; and (4) greater concentration of power in an individual unit.

In general, we consider further improvement of the internal efficiency of the turbine itself to be secondary, in overall importance, to the adaptation of the turbine to economical service with more efficient thermal cycles. Large turbine Rankine cycle efficiencies are now close to practical upper limits, so we can reasonably assume further improvement along this line will be relatively small, and that substantial improvement may well prove to be unjustifiably costly. On the other hand, thermal cycle improvements have even recently led to materially lowered heat rates, and such development is still believed to be potentially the more promising.

It is helpful to consider probable steam conditions of the future in the light of their development in the past. For this purpose Fig. 1 shows the advance of throttle steam pressure and temperature against time, for condensing turbines. We have intentionally omitted a single instance in which 2300 lb steam pressure was adopted, for the purpose of more clearly showing the broad trend. Present-day new installation steam pressures are generally of the order of 650, 850 or 1250 psi at the turbine throttle, with corresponding steam temperatures of about 825, 900 and 950 F, respectively. The 850-psi class is currently the most common selection, with the 1250-psi class apparently gaining in popularity. The essential facts represented by this chart are well known and do not require detailed discussion. One is now primarily concerned with what may reasonably be predicted for the near future in the way of practical steam pressures and temperatures.

Increase of steam pressure, at a given temperature, tends to lower the Rankine cycle efficiency of the turbine, due to increased leakage loss in high-pressure turbine stages and to greater moisture loss in the exhaust end blading. On the other hand, increase of steam temperature, at a given pressure, improves turbine efficiency by decreasing leakage and moisture losses. Despite its adverse effect on turbine efficiency, increased steam pressure generally results in reduced heat rate of the turbine alone, as does, of course, increased steam temperature. The potential gain in heat consumption with higher steam pressure is particularly important, however, when used with the regenerative feedwater-heating cycle, as the limiting practical final feedwater temperature increases along with the steam pressure. The increment of potential gain in heat rate of the turbine and its feedwater-heating system decreases sharply as the pressure level is raised;

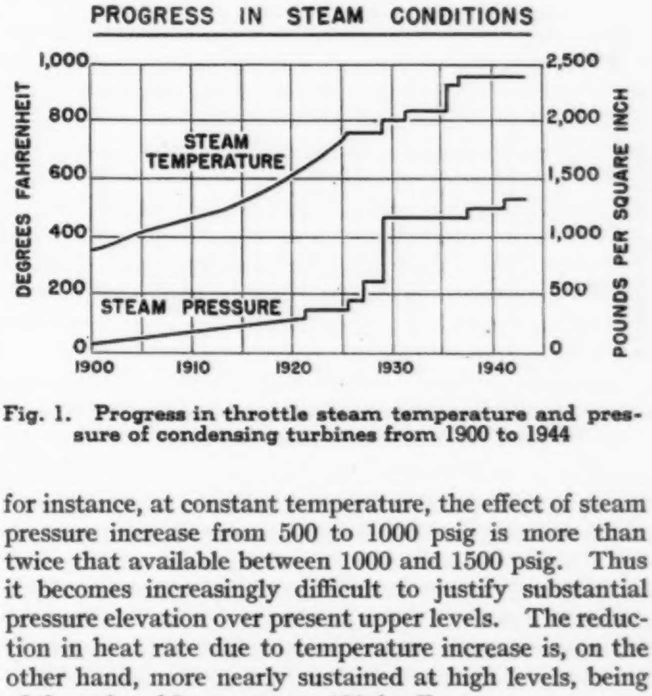



**Fig. 1. Progress in throttle steam temperature and pressure of condensing turbines from 1900 to 1944**

for instance, at constant temperature, the effect of steam pressure increase from 500 to 1000 psig is more than twice that available between 1000 and 1500 psig. Thus it becomes increasingly difficult to justify substantial pressure elevation over present upper levels. The reduction in heat rate due to temperature increase is, on the other hand, more nearly sustained at high levels, being of the order of 3 per cent per 100 deg F.

Steam pressures and temperatures may not properly be considered as independent variables. With the advent of large, high-speed exhaust blading, the problem of inlet edge erosion of such blades operating in wet steam was encountered. Experience has led to a general criterion that the exhaust steam moisture content should not exceed about 12 per cent, in order to limit last-row blade deterioration to a reasonable economical level. This limit is believed to be about right, even though a few entirely successful units have now operated for several years with somewhat higher exhaust moisture, and with present maximum blade-tip speeds of 1256 ft per sec. The exhaust moisture criterion really means

that, for a given exhaust pressure and turbine efficiency, and for the moment excluding the reheat cycle, there is a fairly definite upper limit of pressure for any specific throttle steam temperature. For present-day large turbine efficiency levels, and with $1^1/_2$ in. absolute exhaust pressure, this limit is about 600 psi at 800 F, 900 psi at 900 F, and 1500 psi at 1000 F total steam temperature.

A far more important and realistic phase of the problem arises in determining how high it is practical to go in steam temperature without jeopardizing the plant investment through lowered availability. In this connection, consideration must be given not only to the turbine, but also to the boiler, superheater and auxiliaries. By systematic increase over the past several years there has now been accumulated a reasonable amount of experience in operation at 950 F. This level was reached through a series of logical advances beyond 750 F, and has resulted in a reasonable minimum of difficulty consistent with progress. Such procedure should continue to set the pattern for any further temperature increase, as metallurgical development, together with design and operating experience, should be proved at each step of the way upward.

### *Creep Characteristics Important*

The physical properties and the creep characteristics of existing turbine alloys at elevated temperature have been quite well established by research. It is well known that working stresses must be sharply reduced at high temperature in order to avoid excessive plastic deformation, or creep, in service. The complete answer is not in the building of heavier stuctures to obtain lower steady-state stresses, as, for instance, by merely increasing cylinder wall and flange thickness in the inverse ratio of the change of allowable stress. At some point such equipment would become very poorly adapted to the nonuniform and often rapidly changing high temperatures which are encountered in normal turbine service.

At some point in this development there will be need for a new or modified group of alloys, suitable for casting, forging, welding and machining, and which are capable of supporting very much higher stresses under long exposure to high temperatures than is the case with those alloys now available and in general use. It is to be hoped these alloys will not be exorbitant in cost. In high-temperature equipment, particularly when operated with variable temperature, uniform thin metal sections are very desirable, but unfortunately, in the steam-power cycle, high temperatures and high pressures usually go together. This variable temperature problem, with its transient inequalities of metal wall temperature, is the primary consideration in determining the practical upper temperature limit, since one is interested in long-lived, reliable, low maintenance machinery.

From existing experience at 950 F it is believed that an exploratory increase to 1000 F is justified with present available and proved materials, but that experience at this advanced temperature level should then be thoroughly assimilated before venturing further. With 1000 F temperature, steam pressure could be advanced to about 1500 psi without obtaining excessive exhaust moisture. The potential reduction in heat rate at 1500 psi and 1000 F, as against 1250 psi at 950 F, is of the order of 3 per cent, the total gain being about equally due to the elevation of pressure and to temperature. It is suggested, however, that the initial step be taken in temperature increase only rather than to combine it with 20 per cent increase in pressure over the present 1250-psi level.

A coordinated, war-born program of metallurgical research on high-temperature alloys is in progress. This effort is concerned primarily with alloys for use at temperatures far beyond those now contemplated for steam plants and, in large part, for use in comparatively short-lived equipment. Excellent materials have been developed for these purposes, but as yet they are available only in relatively small pieces; they are difficult to fabricate and very expensive. Forgings, by their very nature, are not most ideally suited to high-temperature service. Precision casting has been found well adapted to the production of repetitive small and intricate parts with many of these new alloys, and it is not unreasonable to expect that steam-turbine blades, among other details, may ultimately be produced in this manner. It is also reasonable to assume that the steam power plant of the future will profit in many other ways from other phases of the current metals research, but not until attention can again be focused on the extended period behavior of suitable alloys.

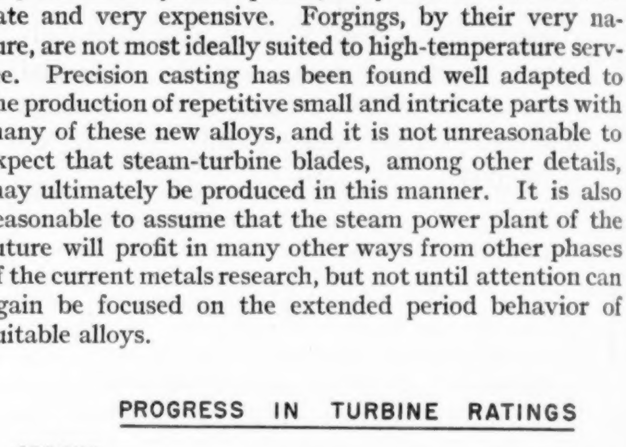



**Fig. 2 Progress in ratings of condensing turbines from 1900 to 1944**

The foregoing has considered future possibilities as they are related to high-grade regenerative feed-heating cycles, in accordance with general American practice, for which more or less standard turbines are now readily adapted. Since the maximum practical operating steam temperature is now such an obvious limitation, it is natural that alternatives be carefully considered. One such variation is the addition of immediate reheat to the multistage feed-heating cycle. With a single stage of boiler reheat, comparable heat rates may thus be obtained with approximately 150 deg F reduction in top steam temperature, or something like 5 per cent reduction in heat rate may be obtained at equal upper steam temperatures. Investment charges, and operating considerations, have to date ruled this system out in all but very few installations in this country. The reheat cycle is mentioned here with the thought that increased fuel costs in the future may well bring this complex cycle into more frequent use, but then only with the higher unit ratings involving multiple turbine cylinders and with machine designs cut to special pattern for the individual installation.

Growth of individual condensing unit capacity is shown by Fig. 2. The recent rapid growth of 3600-rpm turbines is particularly important, since they have now taken over the bulk of the central station field. They have contributed materially to modern steam plant development and are likely to develop further in available rating.

### *High Rotative Speeds Desirable*

In general, the steam turbine is at best advantage when operating at the highest possible speed of rotation consistent with the provision of proper steam flow areas and area ratios throughout its bladed length. Under otherwise comparable conditions, increased speed reduces the physical size of the unit, particularly the diameter of the bladed portion. By doubling the speed of rotation, rotor diameters might roughly be halved and individual blade lengths be doubled, for equal volumetric steam flow. While this simple relationship might be considerably modified in any specific case, nevertheless it is obvious that dimensions would be very materially reduced, with a corresponding reduction in cylinder-wall and flange thicknesses for a given internal steam pressure. As stated previously, such lighter structures are much better adapted to long and satisfactory use under normal conditions of turbine service, which, with load variation, mean widely changing temperatures throughout the unit. It is entirely reasonable to expect these smaller turbines to deform less in service, and to be capable of more successfully withstanding operation variables. The 3600-rpm condensing turbine development into large capacities has had much to do with the success of elevated steam pressures and temperatures in the modern plant.

The maximum economical rating of a condensing turbine is fixed, within limits of allowable leaving energy loss, by the area of the last blade row annulus, which is, in turn, limited by the permissible stress of both the blade and rotor materials. With large, exhaust-stage blading, the major steady stresses are due to centrifugal force. It is essential, also, that these blade groups be so designed that their relatively low natural vibration frequencies shall not coincide with integral multipliers of possible excitation frequencies, that is, with multiples of rotating speed.

### *Limitations of Exhaust Blading*

Condensing turbine exhaust blading is the least flexible element of the entire unit, since its manufacture involves the use of very expensive and special dies, tools and fixtures. Alterations are difficult, also, because of their critical effect upon blade vibration frequencies. It is approximately correct to say that the remainder of the turbine is therefore designed around an existing low-pressure blade. Creation of new, large exhaust blading is undertaken as a major task. This was done in the mid 1930's, aiming for the largest blades which then seemed practical. This resulted in the development of 20-in. long blades to be carried on a 40-in. diameter rotor for 3600 rpm, and of 40-in. long blades with an 80-in. diameter base for 1800 rpm. The blade tip speed in each case is 1256 ft per sec. The limiting single blade annulus for the lower-speed unit currently has four times the area of the corresponding 3600-rpm turbine, meaning that it can accommodate substantially four times the steam flow, or rating, for a given last-row blade efficiency.

Many of the higher speed units have now been in service upwards to seven years with the present limit blade. There has been some difficulty of a random nature which has led to detail modifications. Experience, on the whole, indicates that when more urgent wartime activity is behind us we will be prepared to develop still larger blading, and larger condensing turbines, to drive two-pole generators. So far as the 40-in. long blade at 1800 rpm is concerned, we have experience with but one turbine, and do not feel that there is any early future need for larger blading at this speed.

### *Preference in United States*

Accepted practice in this country has given a fairly definite pattern to condensing turbine-generator arrangements in central station unit ratings. This has been promoted by a general preference for a single-shaft unit, where practical, and by general agreement on the advantages offered at 3600 rpm; the latter consideration has, in some outstanding cases, been considered to predominate and to justify multi-shaft arrangements in preference to low-speed single-shaft units. To an increasing extent users are selecting unit capacities on the basis of that available at the higher speed, using multiple-exhaust turbines if necessary, to obtain the desired combined unit rating.

On the basis of condensing units capable of continuous output of 125 per cent rating, single-cylinder, single-exhaust flow turbines at 3600 rpm are available for ratings to and including 25,000 kw. By tandem compounding in two cylinders to provide double flow exhaust blading, unit ratings up to 65,000 kw have been obtained at the same speed. It is obvious that this same general plan of compounding could be carried further, and with three and four exhaust-flow paths obtain correspondingly higher rating, still with the single-shaft design. However, such construction has not as yet become common, one reason being that there has been comparatively little demand for unit ratings above 65,000 kw. Meantime, larger machines have generally been designed for 1800 rpm, using single-cylinder, single-exhaust flow for 75,000 to 100,000 kw rating, and tandem construction with double-flow low-pressure blading for still larger units. For extremes of steam pressure, and particularly of temperature, it is felt that the low-speed turbine might well be made multi-cylinder, even if within the volumetric limit of the single-flow exhaust blading. It is expected that the higher speed turbine will before long encroach further on the field of the low-speed unit, both with larger exhaust blading development, and possibly also by further compounding of exhaust flows than is now common practice.

### *Standardization*

Considerable effort has been made by A.I.E.E. and A.S.M.E. Committees toward the standardization of selected large turbine-generator ratings within the field of greatest central-station unit activity, namely, 10,000 to 60,000 kw, inclusive. There is now general agreement on all important factors fixing these turbines. They stand as indicated by the following tabulation, with six individual ratings:

PROBABLE TURBINE STANDARDIZATION

| Rating, Kw | Steam Conditions Psig | Temp, F | In., Hg | Saturation Temp, Top Extraction Point |
|---|---|---|---|---|
| 11,500 | 600 | 825 | 1 1/2 | |
| 15,000 | 600 | 825 | 1 1/2 | 3 stages—285 F |
| 20,000 | 850 | 900 | 1 1/2 | 4 stages—350 F |
| 30,000 | 850 | 900 | 1 1/2 | |
| 40,000 | 850 or 1250 | 900 or 950 | 1 1/2 | |
| | | | 1 1/2 | 4 stages—350 F |
| 60,000 | 850 or 1250 | 900 or 950 | 1 1/2 | 5 stages—410 F |
| | | | 1 1/2 | |

It should be noted that for these units the maximum continuous output is 110 per cent of nominal rating, rather than 125 per cent, as has been customary. Correspondingly, nominal ratings for limit frames have been raised, leaving maximum output substantially unchanged. Standard steam conditions have been assigned to reflect going experience and average economies.

We are strongly in favor of standardization as a principle. There are numerous examples in industry, and in the electrical equipment industry especially, where a rational standardization of product has ultimately proved beneficial to user, manufacturer and to the public. At the same time, it is appreciated thoroughly that to date there has been little practical experience in the standardization of heavy machinery, and its success remains to be proved.

Our large turbine development of the past ten years has stressed the standardization of component details and their design principles, such that they could readily be applied, in appropriate size, to any member of a complete line of machines. Important benefits were realized, not only in the expedition of design, procurement of material and in manufacturing operations, but, also, field operating experience was then readily translated from a single unit to the line as a whole. This led to more rapid solution of operating problems and the attainment of a high overall level of practical dependability, and undoubtedly helped materially in meeting the unprecedented volume demands on the central station industry a few years ago.

### *Greater Standardization in Construction Points to Better Prices and Deliveries*

It is our belief that still more can be gained along this line by focusing greater attention on a limited number of standard condensing frames after fixing the normal variables of steam and extraction conditions at rational values. It is expected that some order of repetitive purchasing can be obtained and, depending very largely on its extent, that the standard unit will show improved deliveries and prices, and thoroughly proved equipment. Deliveries will be materially improved, especially if individual frame activity should become such as to justify the manufacturer carrying a reasonable stock of bottleneck parts if not even of semifinished machines. Specifically, this could be the means of avoiding serious delay such as may now occur if a larger cylinder casting, or rotor forging, is found defective at some advanced stage of manufacture.

As for the effect on price, it is appreciated fully that standardization will fail completely if the price for the strictly standard unit is ultimately not lower than for the tailormade turbine by an amount sufficient to be attractive. On the other hand, until there is some reasonable degree of practical acceptance and use, there are in reality no economies to be obtained from standardization. Just how or when the first step in price adjustment will be made is not of present concern so long as it is known that a price differential will come, possibly even before there has been any realistic justification for such a course.

### *Development Will Not Be Stifled*

Some have expressed fears that standardization may stifle further steam plant development. This fear is quite groundless. If the specifications require, we will offer any steam turbine possible within our range of knowledge, just as we do today, whether within or without the selected standards. Furthermore, the user members of the standardization committees have, for all practical purposes, written the standards, we being primarily interested in assuring that they take full advantage of practical design limits as they now exist. The initial standards may later be increased in scope as steam plant practice advances. In fact, it is not to be expected that long-lived standards are feasible in this or in any other machinery field. A rational revision in the not distant future is entirely in order and it will undoubtedly prove to be an improvement because of development in the art and because it is then based on greater standardization experience.

It is our conviction that nothing short of a serious and cooperative trial will prove just how successful large turbine standardization can be; meantime nothing is lost by the attempt.

# *Changes to Wood-Burning Furnace Doubled Steam Output*

By CHARLES MELLOR*

**These changes involved the installation of a stepped semi-automatic grate supplied by a wood feeder through a refractory arch, the application of water walls to the upper part of the furnace and the addition of an economizer. The auxiliary oil burners were transferred to the rear wall.**

INTERRUPTION in the normal supply of fuel to Argentina, as a result of the war, has necessitated many changes and expediencies by power plants in order to burn local substitute fuels. One such instance concerns an installation in a rubber manufacturing plant in the province of Buenos Aires where a conventional three-drum, oil-fired boiler supplied process steam.

Some two years ago when it became difficult to procure oil, the unit was fitted with a dutch oven at the side of the setting and equipped with a slightly inclined stationary grate for burning wood. This was fired by hand through two access doors, and consisted principally of eucalyptus logs 10- to 12-in. diameter and cut to about 8-in. length. The oil burners were retained to supplement the wood when necessary.

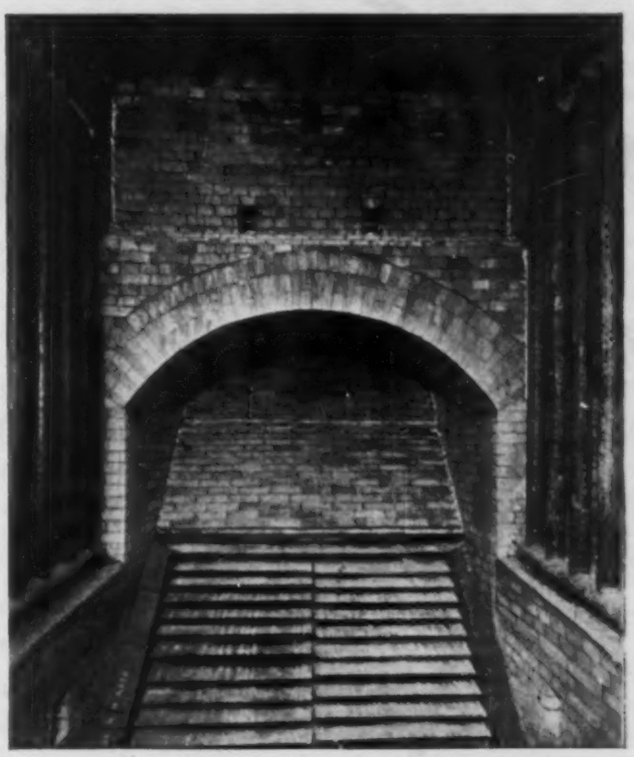
Considerable difficulty, however, was encountered in maintaining the required steam when burning wood and the consequent demands on the very limited oil available caused considerable concern. Moreover, the cost of maintaining the refractories was excessive and shutdowns for refractory repairs became frequent.

The company's engineers therefore decided to eliminate the dutch oven at the side and to install a stepped semi-automatic grate having grilled boxes for the admission of air on either side and a short refractory arch at the entrance end. The fuel is fired by a wood feeder mounted over a short modified form of dutch oven at the front of the setting and falls on an incline under a refractory arch to the top of the stepped grate. This not only cut down on manual labor but also prevented the entrance of excess air to the furnace. To provide room for the new grate, the floor of the combustion chamber was lowered. Also, the oil burners were removed from the front wall and placed in the rear wall under the lower drum.

Finally, in order to meet increasing steam demands, and at the same time to decrease refractory maintenance, it was decided to equip the combustion chamber with water walls. These consisted of $3^1/_4$-in. vertical tubes shielding the upper refractory side walls. A fin-tube economizer was also added and soot blowers were installed to remove the soot and ash accumulations from both the boiler and the economizer surfaces.

In order that there be no interruption in steam supply while these changes were in progress, a large locomotive was rented and piped to the live steam line. However, as the locomotive was equipped with a superheater, and as many of the process machines in the plant were not suited to operation with superheated steam, it became necessary to construct a desuperheater.

Incidentally, in order to avoid the stack discharge from the locomotive becoming a nuisance to the adjacent rubber plant, an improvised stack was made from a series of drums, with heads removed, and extended above the building roof line.

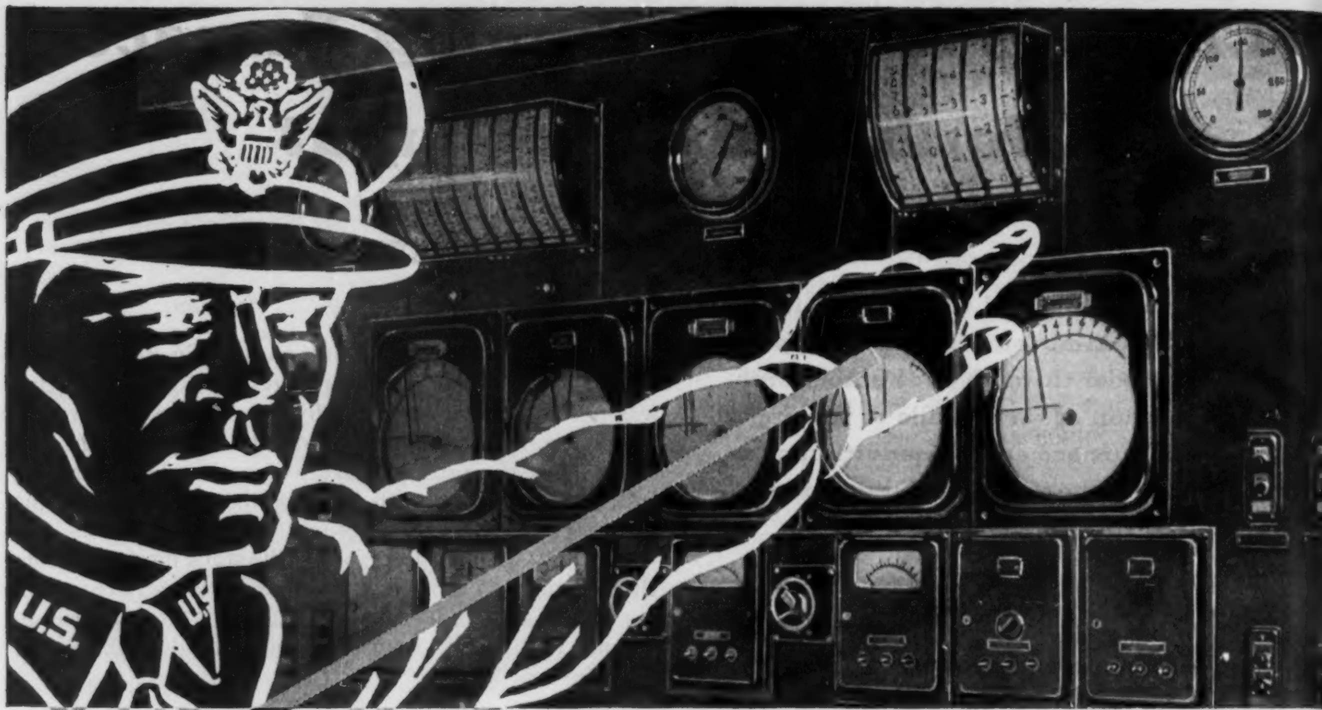


**View looking toward front of furnace after alterations**

Because of the limited time that the locomotive was available, it was necessary for the contracting engineers, Mellor-Goodwin, to coordinate and organize the work in three shifts so as to complete the job in 20 days.

With the changes mentioned the output of the boiler has been more than doubled and the rate of wood consumption has been reduced 30 per cent, based on conditions previously existing. The $CO_2$ content of the stack gases now averages 15 per cent, the excess gas temperatures have been reduced 200 deg C and the unit is now able to handle rapid fluctuations in steam demand.

* Director, Mellor-Goodwin Ltda., Buenos Aires, Argentina, representative of Combustion Engineering Company.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# Early Air Preheaters for Stationary Boilers

THE use of air preheaters to improve the performance of steam-generating units appears to have originated in marine practice well over sixty years ago. The heaters of those days were nearly all of the tubular type employing various tube arrangements such as vertical or horizontal banks of short or long tubes sometimes with the gases passing through the tubes and sometimes over them. Some were more or less standardized products of manufacture adapted to fit a particular type of boiler but many were merely makeshift arrangements.

*First Stationary Application in United States*

The first application of air preheaters in land practice in this country appears to have been about 1881 at a plant of the Pacific Mills in Lawrence, Mass. The air heater, then variously referred to as a heat abstractor, warm-blast apparatus, or hot-draft apparatus, was in this particular instance applied to a horizontal return-tubular boiler and consisted of two horizontal banks of 2-in. diameter lap-welded tubes through which the hot gases passed. Surrounding each 2-in. tube was a 3-in. tube, concentrically arranged but somewhat shorter to allow the air to be passed through the annular space between the inner and outer tubes. It is interesting to read that after extended experiment this apparatus was found to be incapable of reducing the gas temperature below 160 F.

This performance seems to have disappointed the builders, so another heater was designed for an adjacent boiler consisting of 2-in. tubes arranged one inch apart through which spaces the air made several passes across the tube bank. Reported tests indicate that this second heater produced a gas-temperature drop about five degrees greater than the first and gave 12.5 points better efficiency than a similar unit operating without an air heater. After three years of operation this heater was reported to be in good condition. One is not surprised, however, to read elsewhere that considerable trouble from plugging was encountered in some early heaters, since the tube temperature would often be below the dew point of the gas.

This installation of 1881 was the result of an invention of Obadiah Marland covered by U. S. Letters Patent No. 205282 dated June 25, 1878, describing a plate-type air preheater for use in combination with forced- and induced-draft devices. In return for several mill owners' investment toward building and testing the apparatus they were to receive exclusive and free license to its use. However, when the apparatus was constructed in 1881 it was built of tubes instead of flat plates as described by Marland.

The plate-type air heater was first used successfully in land practice in England. The reason for its application may be attributed to economic developments of the coal industry in England about the beginning of the present century. The increased demand which was created about that time for sized washed nut coal suitable for burning on mechanical stokers resulted in the increased production of coal of this type and the consequent accumulation of immense quantities of small screenings. For these there was no demand, although the heat value was around 8500 Btu per lb, and consequently the market price became very low. Even so, it was not found economical to transport this fuel any distance from the mines because it could be burned only at such low combustion rates and with such low efficiency that the freight charge per unit of heat actually utilized was great enough to prohibit its use at this time except at such plants as happened to be in close proximity to the coal mines.

Water economizers were to some extent already in use at this time but presented no great field for improvement in thermal efficiency of the boiler plants for the reason that the steam pressure used in many boiler plants was less than 125 lb per sq in. and the amount of heat which could be recovered by a water economizer was therefore small. Realizing that considerably more heat could be recovered by using air, because of the much higher temperature differential available with this medium, some water economizers were actually converted to air preheaters by simply substituting air for water as the cooling medium. This was not very satisfactory since the rate of heat transfer was low and the power consumption to overcome the resistance was very high. Moreover, tubular air heaters of other designs had been used in marine practice for some years but with no outstanding success. So it was thought advisable and necessary, by those industrially minded scientists and engineers interested in burning this cheap waste fuel smokelessly at higher combustion rates and with higher efficiency, to invent and develop an efficient plate-type heater.

*Advent of the Plate-Type Air Preheater*

It appears that in both Great Britain and America, air heaters were first applied to stoker-fired boiler units to enable poor grades of coal to be burned at higher combustion rates with the object of increasing steam output and decreasing cost. That satisfactory results were obtained and these objectives reached was not, however, the reason for the great popularity that was soon to be accorded the plate-type heater and air heaters in general. The use of preheated air on the early stoker units to which it was applied did improve combustion conditions, overall efficiency and plant capacity but it also increased both furnace and stoker maintenance due to higher furnace temperatures and the effect of preheated air on the stoker parts. There were therefore two limits immediately imposed which had to be considered in applying air preheaters to existing units, and these undoubtedly retarded air preheater development in Great Britain up until the time that the

plate-type air heater was first used successfully in the United States.

*Influence of Pulverized Coal and Water Walls*

At about this time, however, two incidents in the history of steam-power generation occurred, namely the successful application of the water-cooled furnace and pulverized fuel firing. Without these two developments, the use of the enormous amount of air-preheater surface which has been installed would have been neither possible nor necessary. Conversely, the use of air preheaters has greatly enlarged the field of application of both water-cooled furnaces and pulverized fuel firing —in the former case because preheated air partly counteracts the reduction in furnace temperatures caused by water cooling, and in the latter case because it aids in obtaining and maintaining proper ignition of pulverized fuel, thus making it easier to burn low-volatile coal in pulverized form. Air preheaters have also extended the field of application of pulverized coal by providing a satisfactory drying medium by means of which wet coal may be sufficiently dried during the process of pulverization to enable it to be more easily and satisfactorily handled by the transporting, feeding and burning equipment.

In 1922, during which year the first commercial plate-type air heater contract was closed in this country, it so happens that the first contracts for equipment employing steam pressures higher than 400 psi were also closed. With higher steam pressures the minimum final gas temperature obtainable with the boiler alone was correspondingly increased and the maximum obtainable boiler efficiency was at the same time decreased due to higher exit gas temperature. Auxiliary heat recovery equipment, additional to boiler and superheater, was therefore necessary in order to equal or improve the boiler room efficiencies that were possible with lower pressure steam. The water economizer and the air preheater are used for this purpose. However, the advantages of multiple-stage bleeding for feedwater heating have popularized this system to such an extent that water economizers alone fail, in many cases, to produce the desired heat recovery between boiler and stack, and air preheaters must be used. Since the air preheater by itself will generally give the desired heat recovery at lower cost than the combination, an air heater alone is often used when there is no objection to the higher preheated air temperature which results from its installation.

Thus it will be seen that the reasons which promoted the early application of air preheaters have not in themselves been responsible for their widespread use and their present position in the modern boiler room.

*Recuperative and Regenerative Types*

Air heaters are classified as "recuperative" or "regenerative," according to the principle of operation involved. In the recuperative type the two fluids are separated by the heat transfer surface; one fluid flowing continuously on one side and the other fluid on the opposite side. Thus, when tubes are used, one fluid flows inside the tubes and the other outside; or, in a plate type, alternate passages between the plates contain the different fluids. In the regenerative type, the surface is intermittently heated on both sides by the circulation of one fluid, and intermittently cooled on both sides by the other fluid. For example, in the Ljungstrom regenerative heater the surface is installed in a rotor; as the rotor slowly revolves, the heating surface passes from one compartment, in which the hot gas gives up heat, to another compartment in which the air absorbs heat. This design of air preheater, in which the heat-transfer surface is made up of bundles of undulated plates, is built in both the horizontal and the vertical types, according to the space and arrangements in the plant in which it is installed. It weighs much less than either the tubular- or plate-type heaters and is capable of providing preheated air at very high temperatures. It is now widely used in large steam generating units.

There are also several other types of regenerative heaters which are not used in power plants and therefore will not be discussed here. However, it may be of interest to mention that a regenerative type heater was patented by S. Bissel on October 2, 1883. This particular heater was employed in connection with a kiln and consisted of a horizontal rotating cylinder filled with a checkerwork of firebrick. Hot gases were passed through the lower segment of the cylinder and gave up part of their heat to the refractory checkerwork which, in turn, was raised in temperature. Air was passed through the upper segment of the cylinder. As the cylinder rotated, the previously heated refractory was brought into the zone through which the air passed and the latter was raised in temperature. The process was continuous.

# Coal Sampling Discussed at Joint Fuels Meeting

IN a paper before the Joint A.S.M.E.-A.I.M.E. Fuels Meeting at Charleston, W.Va., October 30–31, Bertrand A. Landry of Battelle Memorial Institute discussed missing data on coal sampling which he listed as (1) consist; (2) variability of ash in pieces by the float-and-sink method and by direct analysis of pieces for confirmation of this method; (3) variability of the ash of increments, whereby a large number of increments of a variety of specified large weights are taken to establish the degree of mixing directly; and (4) the collection and analysis of gross samples of a specified number of increments of constant weight to give overall confirmation to the established relations between the variables involved. Each of these points was discussed at length and certain mathematical expressions evolved which space here does not permit reproducing.

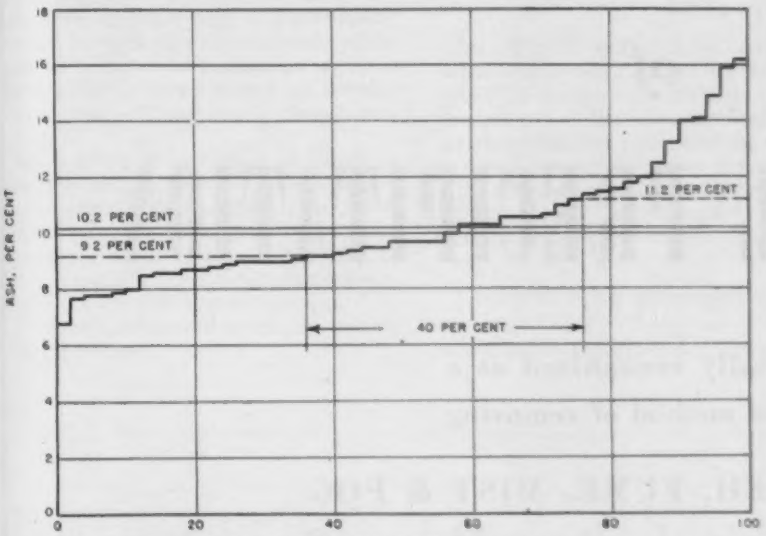


**Fig. 1—Variability of ash percentages of 50 eight-pound increments for a 0 × 2-in. coal from Western Pennsylvania**

In introducing this discussion of sampling, Mr. Landry pointed out that according to the A.S.T.M. "Standard Method of Sampling Coal for Analysis," 1916, which is still in effect, the gross sample must not be less than 1000 lb. For small coals the increment may be 5 to 10 lb, so that from 200 to 100 of them must be taken uniformly over the lot of coal sampled. For run-of-mine or lump, increments may be 10 to 30 lb each, which means that from 100 to 34 increments must be taken to make the 1000-lb gross sample.

Although many gross samples have been taken on this basis, the time and expense involved has often led to the taking of smaller samples. The consistency of the results so obtained eventually brought about an empirical acceptance of the less stringent sampling procedure; but these were not uniform, nor even publicized. Hence, in sampling practice, a situation potentially dangerous was becoming the rule rather than the exception.

The question was reopened by Grumell and Dunningham before the British Engineering Standards Association in 1930 and many studies of the theory and practice of coal sampling followed, including that by an A.S.T.M. subcommittee in 1934 which began to reconsider the specifications for taking gross samples and resulted in the preparation of Tentative Standards, the latest of which is designated as D 492–43T (1943).

The main problem in the field of coal sampling for the last 15 years has been the investigation of the nature of the variability in ash percentage of the coal in relation to the size of pieces, their average ash content and their weight. The usual approach to this study has been rather empirical and has not led, until recently, to specific and definite relations.

Fig. 1 represents the variability in ash content of 50 increments, each of 8 lb, of a raw nut-slack (0 × 2 in.) coal from Western Pennsylvania. Each increment was analyzed separately and the step curve was plotted after rearranging the ash percentages in an ascending order. The horizontal line intersecting the ordinate at 10.2 per cent ash represents the average ash of the 50 increments. The two broken lines at 9.2 and 11.2 per cent define the variation of ± 1 per cent from the average; and it is apparent that of the fifty samples taken only twenty, or 40 per cent, had an ash content within this range of ± 1 per cent from the average. From this a clear idea of the representativeness of a single sample can be obtained. That is, if an 8-lb sample of this coal were taken at random the chances that it would be representative within ± 1 per cent would be only 40 out of 100.

The fundamental fact upon which all sampling is based is that if a number of increments of a specified weight be taken

*Continued on page 59*


**Fig. 2—Comparison of acceptable accuracy of gross samples, according to B.S.I. Standard and A.S.T.M. Tentative Standard**

and combined into a gross sample, the representativeness of the gross sample will be increased as compared to that of the individual increments. By taking a sufficiently large number of increments it is possible to obtain a gross sample such that the probability of its ash content falling within a given range around the true ash content is as great as is desired, although it cannot be achieved.

Gross samples of low variability ordinarily have ash contents which are distributed closely according to a so-called normal low. These are represented in Fig. 2 which have acceptable variability as defined by the British Standards and those of the A.S.T.M.

The Tentative A.S.T.M. Standard calls for a lowering of accuracy or a permissible increase in variability as the average ash of the coal is higher or percentage of ash is lower. This is accomplished by defining the range as ± 10 per cent of the ash percentage.

The number of increments required to give gross samples of acceptable accuracy may be calculated from the relation, $N = V^2/v^2$, where $N$ is the number of increments required, $V$ is the standard deviation of the increments and $v$ is the standard deviation of the acceptable gross samples.

From this the author developed the following relations:

$$N = \frac{\gamma^2 W}{0.15087} \quad \text{as applying to the B.S.I. Standard}$$

and

$$N = \frac{\gamma^2 W}{(0.0020033)y^2} \quad \text{as applied to the A.S.T.M. Tentative Standard}$$

where $\gamma^2 W$ represents the variability of increments of weight $W$ of a given coal, and $y$ is the per cent ash.

Since neither of these equations can be solved for $N$ unless $\gamma^2 W$ is known, the author proceeded to evaluate $\gamma^2 W$ as follows:

$$\gamma^2 W = \gamma^2 w \left(\frac{W}{w}\right)^{(a-1)}$$

where $W$ is the weight of the increment, $w$ is the weight-weighted average of the piece, $\gamma^2 w$ is the measure of variability (standard deviation)² of the ash percentage of the average weight of piece, and the exponent $(a-1)$ expresses the degree of randomness with which the ash is distributed through the lot of coal being sampled. This expression may be written:

$$\log \gamma^2 W = \log \gamma^2 w + (a-1) \log \frac{W}{w}$$

which permits plotting as a straight line.

## Two-Million Volt X-Ray Unit

X-ray pictures can be taken through pieces of steel a foot thick, using a new 2,000,000-volt mobile X-ray unit developed in the Research Laboratory of the General Electric Company at Schenectady. Up to now the most powerful X-ray unit in general use has employed one million volts, more than fifty of which are now actively serving the war effort in the United States and abroad.

In radiographing an 8-in. steel casting the two-million-volt outfit is 78 times as fast as the million-volt. Under one typical set of conditions cited, four and a half hours were required to make an exposure through this thickness with a million volts. Two million volts did it in three and a half minutes. For still thicker sections the ratio is even greater. Two-million-volt X-rays make a satisfactory exposure through a foot of steel in about two hours when the Type A X-ray film is used, at a distance of three feet from the end of the tube. For practical purposes such a thickness is opaque to million-volt X-rays.

Even though the new unit weighs 5000 lb, it is mobile in the sense that it can readily be moved by crane and positioned at any angle by push-button control of fractional horsepower motors. Steel castings of the thicknesses for which it would be used might weigh hundreds of tons and where such masses are handled a two and a half ton X-ray outfit is relatively light.

Like that of one million volts, the new unit makes use of a multiple-electrode tube, in which the electrons, starting from a heated filament at the top, are speeded in stages until they have the total rated energy. After they attain full speed, which for two million volts is about 179,000 miles per second or 96 per cent of the velocity of light, they strike a copper-backed tungsten target at the end of the tube and X-rays are generated. These may either be squirted from the end, like water from a hose, or sprayed from the side. After penetrating the metal specimen, they fall on photographic film which makes the radiograph.

In the million-volt outfit the electrons, on their way to the target, were speeded to twelve steps, but the new tube has 24, averaging 83,500 volts at each stage. Construction of the tube was made possible by the use of rings of fernico between the sections of glass. Fernico is an alloy which expands with heat the same as glass, and so the metal and glass can be fused directly together.

High voltage is supplied by a resonance transformer which has no iron core and the X-ray tube is placed at its axis. Both tube and transformer are in a closed metal tank, 5 ft in diameter and 8 ft long, which contains Freon gas for insulation.

One trouble with X-rays of lower voltage is the great range between exposure times for metals of different thicknesses. If the same specimen has one part that is thin and another that is several times as thick, it is not possible to expose correctly for both at once. The thin parts must be built up to make the exposure the same throughout. Need for this method is eliminated with the million-volt outfit, and to an even greater extent with two million volts. Even though the rays are able to penetrate very thick specimens, they will still not overexpose sections considerably thinner. Excellent radiographs may similarly be taken through objects made of different materials, some of which are much more opaque to X-rays than others.

Another advantage of the high-voltage rays is that the machine may be placed far back from the specimens and a large area sprayed with X-rays as powerful as from a lower voltage tube much closer which would cover only a very small area. Thus, even with smaller pieces of metal that do not require their great penetrating power, high-voltage X-rays are advantageous.

Placing the X-ray tube at a distance from the part being radiographed also increases the accuracy of the pictures by reducing distortion. The rays spread out from the target-like light from a candle. A defect in a casting that is close to the film will appear in its actual size, while one that is considerably nearer to the tube will be enlarged. But when the X-ray generator is well back, both will record correctly.

## To Rebuild Dnieprostroi Development in Russia

International General Electric will supply nine 90,000-kva generators for the U.S.S.R. Dnieprostroi hydroelectric plant. These huge generators, already under construction at Schenectady, will give the famous plant a 15 per cent greater output capacity than it had originally.

The new generators will replace those partially destroyed by the Russians when they retreated before the Germans in 1941. The original generators for the plant, which was completed in 1933, were rated 77,500 kva and 88.2 rpm. The new 90,000-kva units will operate at 83.3 rpm. This decrease in speed, coupled with the increase in kilovolt-amperes, results in an equivalent increase in size of 21 per cent. They will be the largest generators in diameter and total weight ever built.

Hydraulic turbines for the station are being built by the Newport News Shipbuilding and Dry Dock Co. Each of these water wheels will be capable of developing 100,000 hp.

The Dnieprostroi Dam, a reinforced concrete structure across the Dnieper River at Zaporozhe, was blown up by the Russians in August, 1941, when the Nazis invaded that section of the country. The Germans spent more than a year in repairing it and eventually got some power from the station. But late in 1943 when the Russians drove the invaders out of the Ukraine, the Germans completed destruction of the station and the dam.

# REVIEW OF NEW BOOKS

**Any of the books reviewed on these pages may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.**

### Thermodynamic Charts—Second Edition

**By Frank O. Ellenwood and Charles O. Mackey**

Those who have used the charts prepared by these authors in their earlier edition can attest to the convenience of having such a wide range of steam conditions represented graphically in charts only 8″ × 10″ in size. An index chart permits the user to readily locate the chart number covering the steam conditions with which he is working. The indexed steam charts cover the absolute pressure range from 0.20″ Hg to 5500 psi, from wet vapor of 20 per cent moisture content to superheated steam up to 1000 F. A special chart covers low-quality steam.

Two charts on water, which have been redrawn in an improved form for the second edition, are of great convenience to those dealing frequently with heat content and specific volume of hot water at various pressures.

The book contains 46 pages of text and tables. Nearly one-half of the book is devoted to ammonia, freon-12 and psychometric charts; examples of use of charts; velocity tables for ideal nozzles; squares of numbers and common logarithms. Bound in maroon buckram, size $8^1/_4 \times 11$. Price $2.75.

### Proceedings of the 38th Annual Meeting—Smoke Abatement Association of America

This publication comprises some twenty papers and several addresses presented before the 38th Annual Meeting of the Smoke Abatement Association of America held at Detroit, June 6–9, 1944. The topics covered in these talks comprise almost every aspect of the smoke abatement problem, ranging from fuel conservation to meteorological factors. Fly Ash Collection and Control and Overfire Air are subjects which appear in many of the papers, and Smoke Abatement from the standpoint of railroad operation is also amply covered. The discussions which followed the presentation of these papers are also given.

The book comprises 150 typescript pages, printed on one side only, and is bound with paper covers. Price $2.00.

### Technologists' Stake in The Wagner Act

**By M. E. McIver, H. A. Wagner and M. P. McGirr**

In view of an apparent increased interest in collective bargaining on the part of certain groups of technologists who, at the same time, are opposed to representation by labor unions, the authors, under the sponsorship of the American Association of Engineers, have attempted a full explanation of the Wagner Labor Relations Act and the rights of technologists under the Act.

Its administration by the National Labor Relations Board is discussed and various interpretations are cited. From these it would appear that the Board is invested with broad discretion in determining what constitutes employer domination in individual cases and in defining supervisory employees. Moreover, the functions of the Board are compared with those of the War Labor Board. The text is replete with questions and answers and a large number of decisions are cited.

The book comprises 252 pages, plus a bibliography, size 6 × 9 in.; price $2.

# A.S.M.E. ANNUAL MEETING PROGRAM

An extensive program has been arranged for the Sixty-Fifth Annual Meeting of the American Society of Mechanical Engineers, at the Hotel Pennsylvania, New York, extending from Sunday, November 26 through the following Friday. There will be morning, afternoon and evening sessions, approximately sixty in all, with from two to four papers per session, and numerous luncheon and dinner meetings.

All day Sunday and Monday morning will be given over to meetings of Council, various committees and section delegates, and the annual Business Meeting is scheduled for 4 p.m. Monday.

Aside from technical subjects there will be several papers, under the auspices of the Management Division, dealing with the employment of returning service men (Monday evening) and their education (Thursday evening).

As usual, aviation is allocated a substantial part of the program, ranging from a session on helicopters (Monday evening) to the application of gas turbines and jet propulsion for airplanes on Thursday morning. Post-war aviation will be discussed Wednesday afternoon.

Also, the gas turbine as applied to locomotive drive will be the subject of two papers Wednesday afternoon.

The Annual Dinner is scheduled for Wednesday evening at which honors and awards for 1944 will be conferred. Honorary membership will be bestowed upon Charles M. Allen, professor of hydraulic engineering at Worcester Polytechnic Institute; Major General Levin H. Campbell, Jr., Chief of Ordnance, U. S. Army; Vice Admiral Emory S. Land, Chairman, U. S. Maritime Commission; Gano Dunn, President of J. G. White Engineering Corporation; and Sir Standen L. Pearce, Engineer-in-chief of the London Power Company.

That part of the technical program of special interest to power men includes the following papers:

*Monday, 8 p.m.*

"Discussion of Photographic Analysis of Furnace Performance," by representatives of several companies.

"Locomotive Firebox Photographic Analysis," by Walter Leaf, Denver & Rio Grande Western Railroad.

"Some Thermal Effects in Oil-Ring Journal Bearings," by R. A. Baudry, Westinghouse Elec. & Mfg. Co.

*Tuesday, 9:30 a.m.*

"Coefficients of Herschel Type Cast-Iron Venturi Meters," by W. S. Pardoe, University of Pennsylvania.

"Piping Arrangements for Acceptable Meter Accuracy," by R. E. Sprenkle, Bailey Meter Co.

"Axial Vibration of Turbine Disks," by Arthur M. G. Moody, De Laval Steam Turbine Co.

"A General Method for Calculating the Critical Speeds of Flexible Rotors," by M. A. Prohl, General Electric Co.

"Prediction of Centrifugal Pump Performance," by R. J. S. Pigott, Gulf Research & Development Co.

"A Study of the Theory of Axial-Flow Pumps," by George Wislicenus, Worthington Pump & Machinery Corp.

"Ignition Through Fuel Beds of Traveling or Chain-Grate Stokers," by E. P. Carman and W. T. Reid, U. S. Bureau of Mines.

"Handling and Burning Fuels on Board American Ships," by David Schoenfeld, Combustion Engineering Co. and G. P. Haynes, Todd Ship Yards Corp.

*Tuesday, 2:30 p.m.*

Symposium on "Future Trends of Fuel"

*Tuesday, 8 p.m.*

"Mobile Power Plants," contributed by U. S. Navy.

"Boiler Nozzles and Valve Inlets for High Capacity Safety Valves," by E. K. Falls, Clarkson College, and Peter A. Ibold, Manning, Maxwell & Moore.

"External Corrosion of Furnace Wall Tubes," (1) History and Occurrence, by W. T. Reid, U. S. Bureau of Mines, R. C. Corey and B. J. Cross, Combustion Engineering Co.; (2) Significance of Sulphate Deposits and Sulphur-Trioxide in Corrosion Mechanism, by R. C. Corey, Combustion Engineering Co. and W. T. Reid, U. S. Bureau of Mines.

*Wednesday, 9:30 a.m.*

Symposium on "Dust Collection"

Boiler Feedwater Studies

- "Silica Disposition in Steam Turbines," by F. G. Straub and Hilary A. Grabowski, University of Illinois.
- "History of Potassium Treatment at Springdale Station," by L. E. Hankison and M. D. Baker, West Penn Power Co.
- "Experience With Potassium Treatment at Montaup Station," by George V. Parks, Montaup Electric Co.
- "Experience With Potassium Treatment at Windsor Station" by W. L. Webb, American Gas & Electric Service Corp.
- "Efficiency of Extended Surface," by Karl A. Gardner, The Griscom-Russell Co.

*Wednesday, 2:30 p.m.*

"Tube Spacing in Finned Tube Banks," by S. L. Jameson, General Electric Co.

"A General Correlation of Friction Factors for Various Types of Surfaces in Cross Flow," by A. Y. Gunter and W. A. Shaw, Alco Products Div., American Locomotive Co.

"Air-Cooled Steam Condensors," by R. A. Bowman, Westinghouse Elec. & Mfg. Co.

*Thursday, 9:30 a.m.*

"Practical Aspects of Feedwater Treatment for Locomotive Use," by T. H. Hislop, New York Central System.

"Carryover in Locomotive Boilers," by Arthur Williams, Superheater Co.

*Thursday, 2:30 p.m.*

"Disk Extended Surfaces for High Heat Absorption Duty," by G. E. Tate and John Cartinhour, Foster Wheeler Corp.

"Heat Flux Pattern in Fin Tubes Under Radiation and Relative Efficiency of Fin Tubes in Convection Zone," by A. R. Mumford and E. M. Powell, Combustion Engineering Co.

*Thursday, 8:00 p.m.*

Symposium on "Metallurgy of Marine Engineering."

"High-Speed Heating, Fuel-Fired Techniques and Their Possibilities" by F. O. Hess, Selas Corporation of America.

"Induction Heating Techniques, With Frequency Analyses and Notes on High Power Concentrations," by Wesley M. Roberts, Radio Corporation of America.

*Friday, 9:30 a.m.*

Panel Discussion on "Measurements of Heat Absorption in Furnaces"—Eight speakers on boiler furnaces and four on industrial furnaces.

"Graphitization of Low Carbon and Low Carbon-Molybdenum Steels," by H. J. Kerr and F. Eberle, Babcox & Wilcox Co.

"Progress Report on Graphitization of Steam Lines," by S. L. Hoyt and R. D. Williams, Battelle Memorial Institute.

*Friday, 2:30 p.m.*

"Investigation of Graphitization at Detroit," by R. M. Van Duzer and Arthur McCutchan, The Detroit Edison Co.

## Recovery of Coal From Mine Refuse

At least one ton of mine refuse is produced for each ten tons of bituminous coal marketed in the Pittsburgh area, according to an investigation by the U. S. Bureau of Mines. The ratio at mechanized mines ran as high as one ton of refuse for every three tons of coal whereas with hand-loading operations, the ratio was about 1 to 20. This refuse comes from falls of roof, cleaning-up operations and material that has been rejected in hand picking. Some of the mines in the Pittsburgh area already are recovering coal from such refuse, while many others are not.

The Bureau estimates that it would be possible to recover about a million tons of usable coal from this source annually in this area and additional proportionate tonnages in other large coal-producing centers. Hand picking by unskilled labor or recovery by coal-washing equipment are the methods suggested.

Bearing out this contention, engineers of the Bureau recently sampled a load of nearly 17,000 lb of typical refuse fresh from the mine and found that it contained more than 2500 lb of coal suitable for industrial use.

## New Officers of American Welding Society

Officers of the American Welding Society who were installed at the Annual Meeting held in Cleveland, Ohio, October 16 to 19, are:

President, A. C. Weigel, vice president, Combustion Engineering Company, Inc., New York; First Vice President, Isaac Harter, vice president, The Babcock & Wilcox Company, Barberton, Ohio; Second Vice President, Dr. W. F. Hess, Assistant Professor in Metallurgical Engineering, Rensselaer Polytechnic Institute; Treasurer, O. B. J. Fraser, Director of Technical Service on Mill Products, International Nickel Company, New York; Secretary, M. M. Kelly, Society Headquarters.

President A. C. Weigel

Directors of the Society taking office were: Roger W. Clark, Welding Engineer, General Electric Company; L. W. Delhi, Vice President, Western Pipe & Steel Company, San Francisco, Calif.; J. F. Lincoln, President, Lincoln Electric Company, Cleveland, Ohio; H. Malcolm Priest, Engineer of the Railroad Research Bureau, United States Steel Corporation Subsidiaries.

## Slight Downward Trend in Electric Output Indicated

Peak demands of the principal electric utility systems in September of this year reached 36,319,373 kw which was a gain of 41,000 kw over the preceding month and approximately 3.5 per cent over the figure for September 1943. However, preliminary figures issued by the Federal Power Commission show the total September 1944 output of 18,468,061,000 kwhr to be about a billion kilowatt-hours under those of August and 0.7 per cent under September 1943, thus indicating that a downward trend has set in, if seasonal demands be excluded. The Commission's estimate for the total 1944 output is approximately 226 billion kilowatt-hours with a December peak of nearly 38 million kilowatts.

The rated generating capacity as of September 30, 1944, was 50,163, 194 kw.

# NEW CATALOGS AND BULLETINS

**Any of these publications will be sent on request**

### Air Filters

Air Devices, Inc., has issued an attractive 16-page bulletin (AF 44-1) describing its line of AGITAIR Air Filters for air conditioning, ventilating, heavy-duty industrial, and grease removal applications. The bulletin is generously illustrated and gives engineering data for its various types of filter units. AGITAIR Diffusers and Exhausters are also briefly described.

### The Bowes Drive

The Elliott Company has issued an illustrated 4-page folder on the new engine type nonreversing Bowes Drive which comprises a new electric device for the reduction of speed between high-speed prime movers and drive shafts. The Bowes Drive is built in two types, reversing and nonreversing, by Elliott Company as licensee. Its immediate application is for ship propulsion where (by wholly electrical means) the speed of modern prime movers is reduced to the lower speeds required for efficient propeller operation. The unit also provides power for auxiliary service loads through slip ring take-off circuits, and can be used as a source of electrical power for cargo handling when disengaged from its primary job of speed reduction.

### Ion Exchangers

Infilco Incorporated has issued a 12-page bulletin (No. 1960) featuring its line of sodium, hydrogen and anion exchangers. The use of the various ion exchangers are described and typical installations of exchange equipment are illustrated by diagrams and photographic halftones.

### C-E Spreader Stoker

Combustion Engineering Company has issued a revised 16-page catalog (No. SS-3) featuring the salient design, drive and operational features of the C-E Spreader Stoker. This new edition contains many new detail and installation views, also additional application arrangements and a new page on marine application.

### Bursting Pressures of Seamless Steel Tubing

Globe Steel Tubes Company has issued a 24-page bulletin (No. 112) tabulating the bursting pressures of seamless steel tubing from $^{1}/_{8}$ in. to $9^{3}/_{8}$ in. O.D. as calculated from Barlow's formula. Technical service on tubing problems is also mentioned in this handy booklet.

### Tachometers

Reeves Pulley Company has issued an 8-page bulletin (G-448) which illustrates and describes the speed indicating and speed recording Tachometers which it offers as accessories for the Reeves Variable Speed Control units. Mechanical and electrical types are illustrated with line cuts and photographic halftones.

### Refractories

Harbison-Walker Refractories Company has issued a colorful 8-page bulletin featuring its H-W fireclay refractories produced from the flint and plastic clays of the Kentucky-Southern Ohio district. H-W insulating firebrick and high-temperature bonding mortars produced in another locality are also described.

## Advertisers in This Issue